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FORAMINIFERA OF LATEST CRETACEOUS AND EARLIEST TERTIARY AGE IN THE NEW JERSEY COASTAL PLAIN

RICHARD K. OLSSON

Rutgers, the State University, New Brunswick, New Jersey

ABSTRACT—The Redbank, New Egypt, and Hornerstown formations have yielded a total of 184 species of Foraminifera, 44 of which are new. Benthonic and planktonic Foraminifera from the Redbank sand and the lower part of the New Egypt sand suggest a post Navarroan-pre Tertiary age. The occurrence of Tertiary species, especially species of *Globorotalia*, in these faunas emphasizes the very late Cretaceous age. The Hornerstown greensand and the upper part of the subsurface New Egypt sand contain several planktonic faunas. These represent the Early Paleocene *Globorotalia compressa-Globigerinoides daubjergensis* zone, the Late Paleocene *Globorotalia pseudobulloides* subzone of the *Globorotalia angulata* zone, and the oldest part of the subzone of *Globorotalia velascoensis-Globorotalia acuta-Globigerina spiralis*. The latter is believed to be Early Eocene in age. A benthonic fauna from the upper part of the Hornerstown greensand is inconclusive as to either Paleocene or Eocene age.

INTRODUCTION

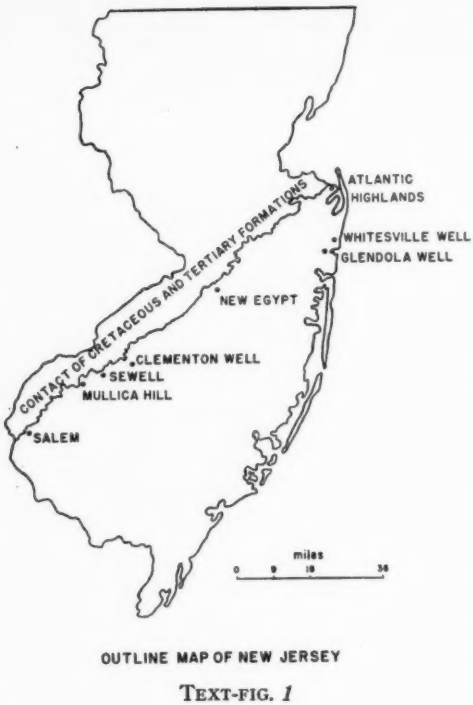
THE latest Cretaceous and earliest Tertiary formations of the New Jersey Coastal Plain are exposed at the surface in a thin band, which extends from Atlantic Highlands in a southwestern direction to the town of Salem by the Delaware River (Fig. 1). The formations dip gently to the southeast with dips of less than 50 feet to the mile. This study is concerned with the Foraminifera of the Redbank, New Egypt, and Hornerstown formations. It is part of a broader stratigraphic study of the latest Cretaceous and earliest Tertiary formations in New Jersey. A brief summary of the stratigraphy, age, and correlation is given; but the main purpose is to present the systematic descriptions of the Foraminifera. The stratigraphy will be more fully discussed in another publication.[1]

[1] Paper submitted to A.A.P.G.

PREVIOUS WORK

In 1907 Weller completed a detailed study of those formations in the New Jersey Coastal Plain which he believed to be Cretaceous in age. He considered the macrofaunas of the Redbank and Tinton formations to be equivalent to those of the late Cretaceous Ripley formation of the Gulf Coast. He also regarded the Hornerstown macrofossils as Cretaceous in age. However in 1929 Cook and Stephenson's study of the Hornerstown molluscs and brachiopods indicated an Eocene age (the Paleocene was not regarded as a separate epoch at that time). Later Stephenson, et al. (1942) included the Redbank and Tinton formations in the *Exogyra costata* zone and correlated these formations with the upper parts of the Gulf Coast Navarro group. Miller's (1956) study of the Hornerstown macrofossils indicated a Paleocene age.

Prior to the twentieth century little work



OUTLINE MAP OF NEW JERSEY

TEXT-FIG. *1*

on fossil Foraminifera had been accomplished in New Jersey. In 1898 Bagg completed a study of the Foraminifera of the New Jersey Coastal Plain. However at that time detailed stratigraphic divisions had not been made, so that it is not clear in many cases from what formation a given specimen was identified. Jennings (1936) described Cretaceous and Tertiary Foraminifera from the New Jersey Coastal Plain. In his study he included a fauna from the uppermost part of the Hornerstown formation. He considered the Hornerstown fauna to be allied with that of the Nanafalia formation of the Wilcox group of Alabama. Recently, Loeblich and Tappan (1957) described the planktonic Foraminifera from the uppermost part of the Hornerstown formation. They placed the Hornerstown in the Paleocene. However, to date no comprehensive study has been completed on the Foraminifera of the formations included in this study. With the location of fossiliferous surface exposures and the availability of cored well material, which have yielded well preserved faunas, it has been possible to obtain a more thorough understanding of the microfaunas from these formations. Unfortunately, no identifiable Foraminifera have been obtained from the Tinton formation.

LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY

On a lithologic basis, the upper Cretaceous and lower Tertiary rocks of the New Jersey Coastal Plain have been divided into five units. One of these is new. In northern Coastal Plain surface exposures the sequence is the Navesink clayey glauconite sand, the Redbank quartz sand (which is divided into two members; the Sandy Hook and the Shrewsbury), the Tinton quartz-glauconite sandstone, and the Hornerstown greensand (Fig. 2, right side). In the central part of the outcrop area (New Egypt) the Tinton quartz-glauconite sandstone appears to be replaced by a glauconite sand, and in the Whitesville and Glendola wells this lithic unit, on faunal evidence, represents both the Tinton and the Hornerstown formations (Fig. 2, left side). This unit, not previously recognized, is defined as the New Egypt glauconite sand.

Biostratigraphic studies have led to the recognition of various faunas and corresponding zones. Weller (1907) regarded the *Belemnitella americana* zone as a guide to the Mt. Laurel and Navesink formations, and Stephenson et al. (1942, p. 448) recognized the Cretaceous *Exogyra costata* zone as including the Navesink, Redbank, and Tinton formations.

The planktonic foraminiferal faunas reveal the farther presence of several distinct faunal zones (Fig. 5).

(1) The zone of *Rugoglobigerina jerseyensis* n. sp.—*Globorotalia monmouthensis* n. sp.; this includes the Redbank sand, the Tinton sandstone, and the lower part of the New Egypt in the subsurface.

(2) The zone of *Globorotalia compressa*—*Globigerinoides daubjergensis*, which includes the basal part of the Hornerstown greensand and the basal part of the upper New Egypt sand in the subsurface.

(3) The zone of *Globorotalia angulata* which includes:

(a) The subzone of *Globorotalia pseudobulloides*, which includes the middle part of

the Hornerstown greensand and the middle part of the subsurface New Egypt sand.

(b) The subzone of *Globorotalia velascoensis — Globorotalia acuta — Globigerina spiralis.* The basal part of this subzone, in which only *G. spiralis* is present, is found in the upper part of the Hornerstown greensand and in the upper part of the subsurface New Egypt sand.

The Cretaceous-Tertiary boundary is apparently represented in some areas by a small disconformity. Elsewhere it lies within a single lithic unit, with no suggestion of any physical break. The Paleocene-Eocene boundary also lies within a formation.

AGE AND CORRELATION

The Redbank microfauna is allied with the upper parts of the Gulf Coast Navarro group and with the latest Cretaceous *Abathomphalus mayaroensis* zone of Trinidad. However, the presence of several species of benthonic and planktonic Foraminifera (including the genus *Globorotalia*) heretofore recognized only from the Tertiary suggests a post-Navarroan age possibly younger than the *Abathomphalus mayaroensis* zone of Trinidad.

The microfaunal of the lower part of the New Egypt sand is clearly Cretaceous in age and like the Redbank sand contains new Tertiary elements, which suggest a very late Cretaceous (post-Navarroan) age. This part of the New Egypt sand appears to be equivalent in age to the Tinton sandstone into which it grades laterally.

The upper part of the New Egypt sand and the Hornerstown greensand contain several Tertiary planktonic zones (Fig. 2). Loeblich and Tappan (1957) established planktonic zones for the Paleocene and part of the Eocene of the Atlantic and Gulf Coastal Plains and correlated them with certain European sections. The close correspondence of the upper subsurface New Egypt and the Hornerstown planktonic faunas to these zones is significant (Fig. 2). The lowest zone, the *Globorotalia compressa –Globigerinoides daubjergensis* zone, is Early Paleocene in age and is equivalent to the type Danian of Europe, the lower Midway group of Alabama and the Midway group of Texas. The *Globorotalia pseudobulloides* subzone of the *Globorotalia angulata* zone is Late Paleocene in age and equivalent to the Thanetian substage of Europe and to the upper Midway group of Alabama. The *Globorotalia velascoensis–Globorotalia acuta–Globigerina spiralis* subzone of the *Globorotalia angulata* zone, contrary to Loeblich and Tappan's (1957, p. 1114) opinions of a Paleocene age, is believed to be Early Eocene in age and equivalent to part of the Sparnacian substage of Europe.

The uppermost part of the Hornerstown formation contains approximately as many species of benthonic Forminifera in common with the Midway of the Gulf Coast as with beds stratigraphically higher.

ACKNOWLEDGMENTS

This study was completed in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Princeton University. The writer wishes to express his gratitude to Dr. Steven K. Fox, Rutgers University, who suggested this study as a long range program, while the author was a graduate student at that University. Sincere appreciation is due to Dr. Alfred G. Fischer, Princeton University, who provided advice on biostratigraphy and suggestions for the preparation of the microfaunal plates. Dr. Fox and Dr. Fischer critically reviewed the manuscript.

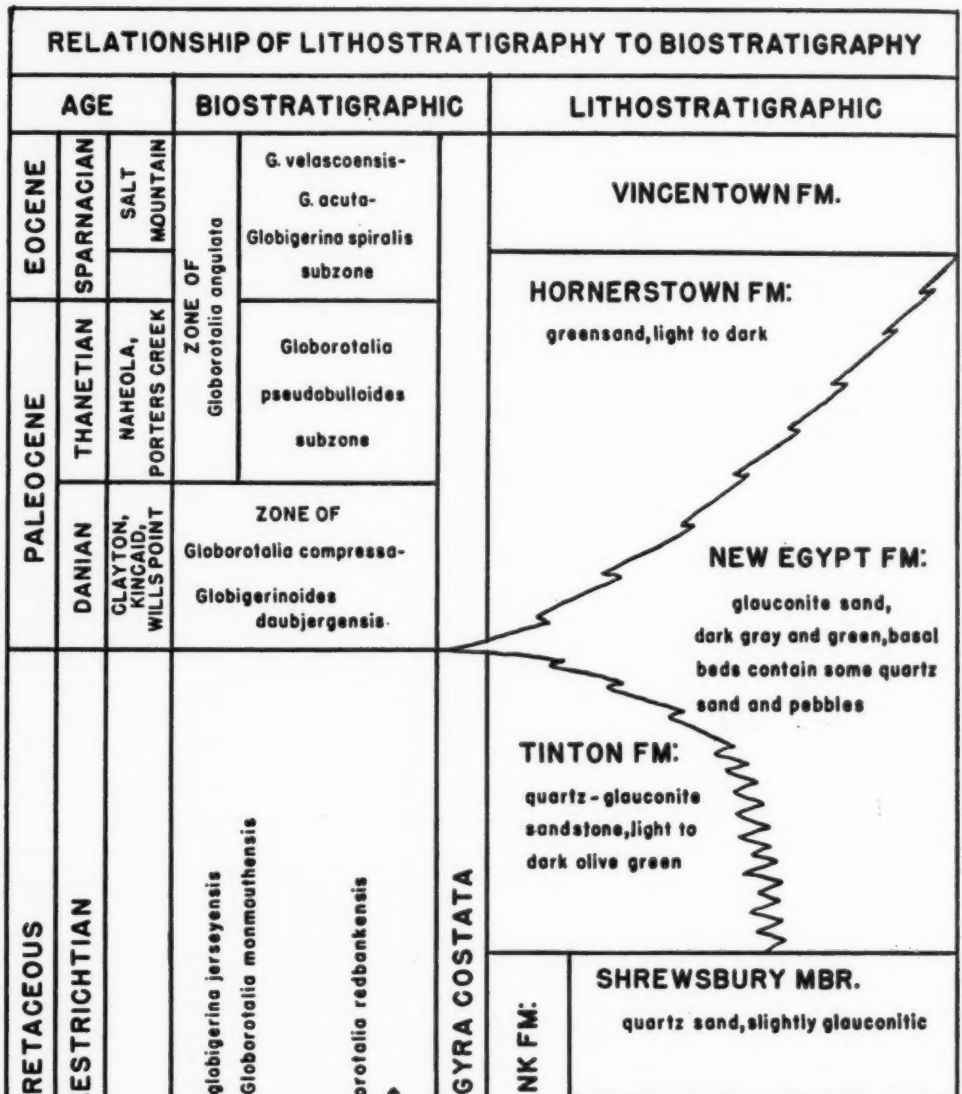
Dr. Alfred R. Loeblich extended the facilities of the United States National Museum for comparisons with type specimens of Forminifera. The department of Geology of Rutgers University loaned the University's collections of Coastal Plain Foraminifera for comparison. Foraminiferal collections at Columbia University also were examined.

The Foraminifera were drawn by Lawrence and Patricia Isham, scientific illustrators, of the United States National Museum.

LOCALITIES

The following are localities which have yielded Foraminifera and to which reference is made (detailed sections are to be published elsewhere).

NJK-101, Redbank formation (Sandy Hook member?), 3½ miles northwest of New Egypt, New Jersey, east side of Walnford-New Egypt road on Nutt Creek, an east-


RELATIONSHIP OF LITHOSTRATIGRAPHY TO BIOSTRATIGRAPHY
AGE
BIOSTRATIGRAPHIC
LITHOSTRATIGRAPHIC
EOCENE
SPARNACIAN
SALT MOUNTAIN
PALEOCENE
THANETIAN
NAHEOLA, PORTERS CREEK
DANIAN
GLAYTON, KINCAID, WILLS POINT
CRETACEOUS
MAESTRICHTIAN
NAVARRO
ZONE OF Globorotalia angulata
G. velascoensis-
G. acuta-
Globigerina spiralis
subzone
Globorotalia
pseudobulloides
subzone
ZONE OF
Globorotalia compressa-
Globigerinoides
daubjergensis
ZONE of Rugoglobigerina jerseyensis
Globorotalia monmouthensis
Range of Globorotalia redbankensis
EXOGYRA COSTATA
VINCENTOWN FM.
HORNERSTOWN FM:
greensand, light to dark
NEW EGYPT FM:
glauconite sand,
dark gray and green, basal
beds contain some quartz
sand and pebbles
TINTON FM:
quartz - glauconite
sandstone, light to
dark olive green
REDBANK FM:
SHREWSBURY MBR.
quartz sand, slightly glauconitic
SANDY HOOK MBR.
quartz sand, clayey, micaceous,
slightly glauconitic, more so at
base
NAVESINK FM:
glauconite sand, clayey, light gray, some
quartz in basal beds

TEXT-FIG. 2

flowing tributary to Crosswicks Creek.

NJK-102, New Egypt and Hornerstown formations, 1½ miles north of New Egypt, New Jersey, 200 yards west of New Egypt-Cream Ridge road on south bank of Contact Creek, a west-flowing tributary to Crosswicks Creek.

NJK-103, Redbank formation (Sandy Hook member), one mile west of Highlands, New Jersey, railroad station at base of Atlantic Highlands bluff on south side of road parallel to Bay Avenue.

NJT-1, Hornerstown formation, approximately 1 mile north of New Egypt, New Jersey, on north bank of Shingle Run, an east-flowing tributary to Crosswicks Creek.

NJT-5, Hornerstown formation, ½ mile northwest of Birmingham, New Jersey, in pit of Permutit Company.

NJT-11, Hornerstown formation, approximately one mile north of New Egypt, New Jersey, on east side of Crosswicks Creek opposite mouth of Shingle Run.

NJT-12, Hornerstown formation, approximately one mile north of New Egypt, New Jersey, 50 feet north of NJT-11 on east side of Crosswicks Creek opposite mouth of Shingle Run.

NJT-19, New Egypt and Hornerstown formations, marl pit approximately ½ mile southeast of Sewell, New Jersey.

NJT-33, New Egypt and Hornerstown formations, northwest of Brownsville-Laurel Springs, New Jersey, on south bank of south tributary of north branch of Timber Creek, a few hundred yards downstream from Old Garden Lake dam.

Core samples have been used from the Clementon, Whitesville, and Glendola wells, the locations of which are shown in Fig. 1.

DEPOSITION OF TYPES

Holotypes of the new species have been deposited in the U. S. National Museum foraminiferal collections in Washington, D. C. Paratype material has been deposited at Princeton University and Rutgers University. Representative faunal slides have been filed at Princeton University and Rutgers University. These places are abbreviated in the systematic descriptions as: (USNM) U. S. National Museum, (P) Princeton University, and (R) Rutgers University.

SYSTEMATIC DESCRIPTIONS

Family LITUOLIDAE

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES SEWELLENSIS n. sp.

Pl. 1, figs. 1,2

Test.—free, small, compressed, close coiled, planispiral. Equatorial periphery lobate. Axial periphery rounded. *Wall.*—rather finely arenaceous. *Chambers.*—inflated; 4–6 in final whorl increasing rapidly in size. *Sutures.*—radiate, distinctly depressed. *Aperture.*—simple opening at the base of final chamber. Diameter 0.15–0.20 mm.

Remarks.—This species occurs in association with *Trochammina sewellensis* in surface exposures of the glauconite sand of the New Egypt formation. The association apparently indicates poor bottom conditions.

Occurrence.—The species is found in the New Egypt at Contact Creek, at Sewell, and at the NJT-33 locality. It is found in the basal Hornerstown at Contact Creek.

Types.—Holotype (USNM 626434) and paratypes (P 81015 and R 5001) from the New Egypt formation, locality NJT-19.

Family TEXTULARIIDAE

Genus SPIROPLECTAMMINA Cushman, 1927

SPIROPLECTAMMINA WILCOXENSIS Cushman and Ponton

Pl. 1, fig. 3

Spiroplectammina wilcoxensis Cushman & Ponton, 1932, p. 31, pl. 7, fig. 1; Cushman & Garrett, 1939, p. 78, pl. 13, figs. 1,2; Toulmin, 1941, p. 571, pl. 78, fig. 1; Cushman, 1944, p. 8, pl. 1, figs. 1,2; 1944, p. 19, pl. 3, figs. 26,27; p. 29, pl. 5, fig. 1; Brotzen, 1948, p. 34, text. fig. 6-2; Cushman, 1951, p. 6, pl. 1, figs. 21–23; Hofker, 1955, p. 8, pl. 5.

Remarks.—The Hornerstown forms compare well with the type material. The Hornerstown species is slightly larger in overall size. The species is characterized by a broad compressed test, subacute periphery, slightly curved sutures, and the aperture at the base of the apertural face.

Length 0.45 to 0.50 mm. Width 0.25 to 0.30 mm. Thickness 0.20 mm.

Occurrence.—The species is known from the Wilcox of Alabama and the Midway of the Gulf Coast. Brotzen has reported it

from the Paleocene of Sweden. It is a common form in the Vincentown. It is present in the Hornerstown at the Shingle Run locality.

Types.—Figured hypotype R 5047.

Genus TEXTULARIA Defrance, 1824
TEXTULARIA PORTENTA Cushman
Pl. 1, fig. 6

Textularia portenta Cushman, 1947, p. 81, pl. 17, fig. 16; 1951, p. 8, pl. 2, fig. 6.

Remarks.—This species is characterized by the test that increases rapidly in width in the early stages and only slightly in the adult, chambers that increase rapidly in size and height, and the slightly depressed, somewhat oblique sutures. The Hornerstown forms compare well with the type material. They are slightly larger in overall size.

Length 0.40 to 0.70 mm. Width 0.30 to 0.35 mm. Thickness 0.25 mm.

Occurrence.—The only record of this species is from its type locality, the Naheola formation, Alabama. It is rare in the Hornerstown at Shingle Run.

Types.—Figured hypotype R 5048.

Family VERNEUILINIDAE
Genus VERNEUILINA d'Orbigny, 1840
VERNEUILINA MONMOUTHENSIS n. sp.
Pl. 1, figs. 7,8

Test.—short, triangular with plane surfaces, subacute angles, as long as broad, rapidly increasing in width. *Wall.*—smoothly arenaceous, surface moderately coated with sand grains. *Chambers.*—rapidly increase in size as added, last three somewhat inflated. *Sutures.*—flush with surface, slightly depressed between last three chambers. *Aperture.*—an elongate slit at the base of the last formed chamber. Length up to 0.70 mm. Width up to 0.70 mm.

Remarks.—The species is characterized by the short, triangular test with the plane surfaces and subacute angles. It differs from *Verneuilina cretosa* Cushman in the smaller, non-elongate test, more rapid increase in chamber size, and the lack of a serrate periphery.

Occurrence.—This species occurs commonly in the New Egypt of the Whitesville, Clementon, and the Glendola wells. It is present in the basal Hornerstown at Sewell and in the Clementon well.

Types.—Holotype (USNM 626435) and paratypes (P 81016 and R 5002) from the New Egypt formation.

Genus GAUDRYINA d'Orbigny, 1839
GAUDRYINA MONMOUTHENSIS n. sp.
Pl. 1, figs. 4,5

Shape of Test.—elongate, about 3 times as long as broad; triserial portion bluntly angular, rapidly increasing in width, about ½ to ⅓ length of test, biserial portion slightly compressed with essentially parallel sides. *Wdll.*—finely arenaceous, surface moderately to coarsely coated with sand grains. *Chambers.*—rounded, slightly inflated with latest chambers showing greatest degree of inflation, gradually increasing in length so that sides of test remain parallel. 4–6 chambers in biserial portion. *Sutures.*—distinct, slightly depressed, becoming more depressed in last formed portion of test. *Aperture.*—an ovate depression at base of last formed chamber, with a slight tendency in some specimens to become terminal. Length 0.80 to 1.1 mm., breadth 0.40 to 0.50 mm, width 0.25 to 0.40 mm.

Remarks.—This species differs from *Gaudryina rudita* Sandidge in having a larger triserial portion, in possessing the nearly parallel sides of the biserial portion, and in having fewer chambers in the biserial portion.

Occurrence.—This is a common Redbank species. It also occurs in the Navesink formation of New Jersey.

Types. Holotype (USNM 626436) and paratypes (P 81017 and R 5003) from the Sandy Hook member of the Redbank formation, locality NJK-103.

GAUDRYINA BULLOIDES n. sp.
Pl. 1, figs. 12,13

Shape of Test.—elongate, about 2 times as long as broad; triserial portion bluntly angular, rapidly increasing in width, about ½ length of test; biserial portion slightly compressed with essentially parallel sides. *Wall.*—smooth, finely arenaceous, with a few larger grains cemented to the surface. *Chambers*—rounded, inflated, slightly overlapping previous ones, gradually increasing in length so that sides of test remain paral-

lel. 4–6 chambers in biserial portion. *Sutures.*—distinct, depressed, more so in biserial portion. *Aperture.*—an ovate depression at base of last formed chamber, situated at one side of the chamber and directed toward center of test. Length 0.40 to 0.55 mm., breadth 0.30 mm., width 0.20 mm.

Remarks.—This species is similar to *Gaudryina monmouthensis* n. sp. It differs from this species by its smaller size, smoother walls, more inflated chambers, and the position of the aperture.

Occurrence.—This species has been found only in the Redbank formation.

Types.—Holotype (USNM 626437) and paratypes (P 81018 and R 5004) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Genus CLAVULINOIDES Cushman, 1936
CLAVULINOIDES INSIGNIS (Plummer) Cushman

Clavulina insignis Plummer, 1931, p. 138, pl. 8, figs. 1–4; Jennings, 1936, p. 13, pl. 1, fig. 6.
Clavulinoides insignis (Plummer) Cushman, 1937, p. 124, pl. 17, figs. 14–17; Cushman & Todd, 1943, p. 52, pl. 9, fig. 9; Cushman, 1946, p. 39, pl. 10, figs. 8–11; 1950, p. 3, pl. 1, figs. 18,19.
Tritaxia tricarinata Carsey (not Reuss), 1926, p. 27, pl. 6, fig. 4a,b.

Remarks.—This species is identified by the elongate test, triangular cross section, deeply concave sides, and sharply keeled angles.

Occurrence.—This species occurs rarely in the Redbank at New Egypt. It is more abundant in the Navesink formation of New Jersey.

Family VALVULINIDAE
Genus ARENOBULIMINA Cushman, 1927
ARENOBULIMINA CUSKLEYAE Jennings
Pl. 1, fig. 11

Arenobulimina cuskleyae Jennings, 1936, p. 13, pl. 1, fig. 8; Brotzen, 1948, p. 34, pl. 6, fig. 2.

Remarks.—Diagnostic features of this species are the elongate subfusiform test, the last two whorls that comprise the major part of the test, obliquely depressed spiral suture, and the smoothly arenaceous wall.

Diameter 0.30 to 0.35 mm. Length 0.80 to 1.0 mm.

Occurrence.—This species was originally described from the Hornerstown by Jennings. Brotzen has reported its rare occurrence in the Swedish Paleocene.

Types.—Figured hypotype R 5049.

Genus MARSSONELLA Cushman, 1933
MARSSONELLA CONICA n. sp.
Pl. 1, figs. 14,15

Marssonella oxycona Jennings, 1936, p. 14, pl. 1, fig. 11.

Test.—small, conical in shape, almost as long as broad; apertural end concave, initial end bluntly rounded, rapidly increasing in width. *Wall.*—smooth, finely arenaceous. *Chambers.*—early ones none inflated, last formed chambers slightly inflated. *Sutures.*—at sides of test flush with surface to very slightly depressed, distinctly depressed between the last formed chambers. *Aperture.*—a small ovate opening at base of last formed chamber. Height 0.30 mm. Width 0.25 mm.

Remarks.—This species is similar to *Marssonella oxycona* (Reuss). It differs from that species in the considerably shorter test, fewer chambers, and a bluntly rounded initial end.

Occurrence.—The species originally was figured by Jennings from the Mt. Laurel and Navesink formations of New Jersey. It is present in the Redbank at Atlantic Highlands and New Egypt. It also is present in the New Egypt in the Glendola, Whitesville, and Clementon wells.

Types.—Holotype (USNM 626438) and paratypes (P 81019 and R 5005) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Genus DOROTHIA Plummer, 1931
DOROTHIA MONMOUTHENSIS n. sp.
Pl. 1, figs. 9,10

Test.—free, cylindrical, the base rounded and rapidly tapering, sides of biserial portion nearly parallel, about 2 times as long as broad, greatest width at point approximately ⅔'s distance from initial end. *Wall.*—smooth, finely arenaceous. *Chambers.*—earliest whorl with 4 or 5, later triserial, becoming biserial in adult; round, inflated, overlapping, biserial ones increasing more in length than width. *Sutures.*—indistinct in initial portion, distinct in biserial, flush with surface. *Aperture.*—a narrow elongate slit at base of last formed chamber. Length

up to 1.1 mm., Width 0.60 to 0.80 mm., Breadth up to 0.70 mm.

Remarks.—This species is characterized by the cylindrical elongate test, rounded base, and smooth walls.

Occurrence.—This distinctive species occurs in the Redbank at Atlantic Highlands. It is also found in the Navesink formation of New Jersey.

Types.—Holotype (USNM 626439) and paratypes (P 81020 and R 5006) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Genus PERNERINA Cushman, 1933

PERNERINA REDBANKENSIS n. sp.

Pl. 1, figs. 22,23

Test.—small, rounded, subspherical, with a flattened apertural face, early stages indistinct, the last whorl making up the majority of the test. *Wall.*—smooth, finely arenaceous. *Chambers.*—several to a whorl, expanding, becoming flattened in adult, with pillars from floor to roof. *Sutures.*—indistinct, flush with surface. *Aperture.*—a narrow slit, extending from base into face of the chamber. Length 0.30 mm. Width 0.30 mm.

Remarks.—The species is easily identified by the small subspherical test, flattened apertural face, and the internal pillars.

Occurrence.—This species has been found only in the Redbank. It is known from Atlantic Highlands and New Egypt.

Types.—Holotype (USNM 626440) and paratypes (P 81021 and R5007) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Family TROCHAMMINIDAE

Genus TROCHAMMINA Parker and Jones, 1859

TROCHAMMINA SEWELLENSIS n. sp.

Pl. 1, figs. 18,19

Test.—free, small, high trochospiral, spiroconvex. Equatorial periphery lobate. Axial periphery rounded. *Wall.*—rather coarsely arenaceous for size of test. *Chambers.*—inflated, somewhat globular, numerous, 4 in the last whorl. *Sutures.*—spiral side: obscure in early portion of test, slightly depressed in later portion. Umbilical side: radial, depressed. *Umbilicus.*—very shallow. *Aperture.*—a small arch; interiomarginal, umbilical.

Diameter 0.15 to 0.20 mm.

Remarks.—The glauconite sand of the New Egypt carries this species in association

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EXPLANATION OF PLATE 1

FIGS. *1,2—Haplophragmoides sewellensis* n. sp. Holotype. *1*, Edge view. *2*, Side view. From the New Egypt formation. ×227.

3—Spiroplectammina wilcoxensis Cushman and Ponton. *3*, Side view. From the Hornerstown formation. ×75.

4,5—Gaudryina monmouthensis n. sp. Holotype. *4*, Side view. *5*, Edge view, showing slight tendency toward terminal aperture. From the Redbank formation. ×53.

6—Textularia portenta Cushman. *6*, Side view. From the Hornerstown formation. ×75.

7,8—Verneuilina monmouthensis n. sp. Holotype. *7*, Side view, showing aperture. *8*, Top view, showing aperture. From the New Egypt formation. ×75.

9,10—Dorothia monmouthensis n. sp. Holotype. *9*, Side view. *10*, Edge view, showing slit-like aperture. From the Redbank formation. ×53.

11—Arenobulimina cuskleyae Jennings. *11*, Side view, showing aperture. From the Hornerstown formation. ×75.

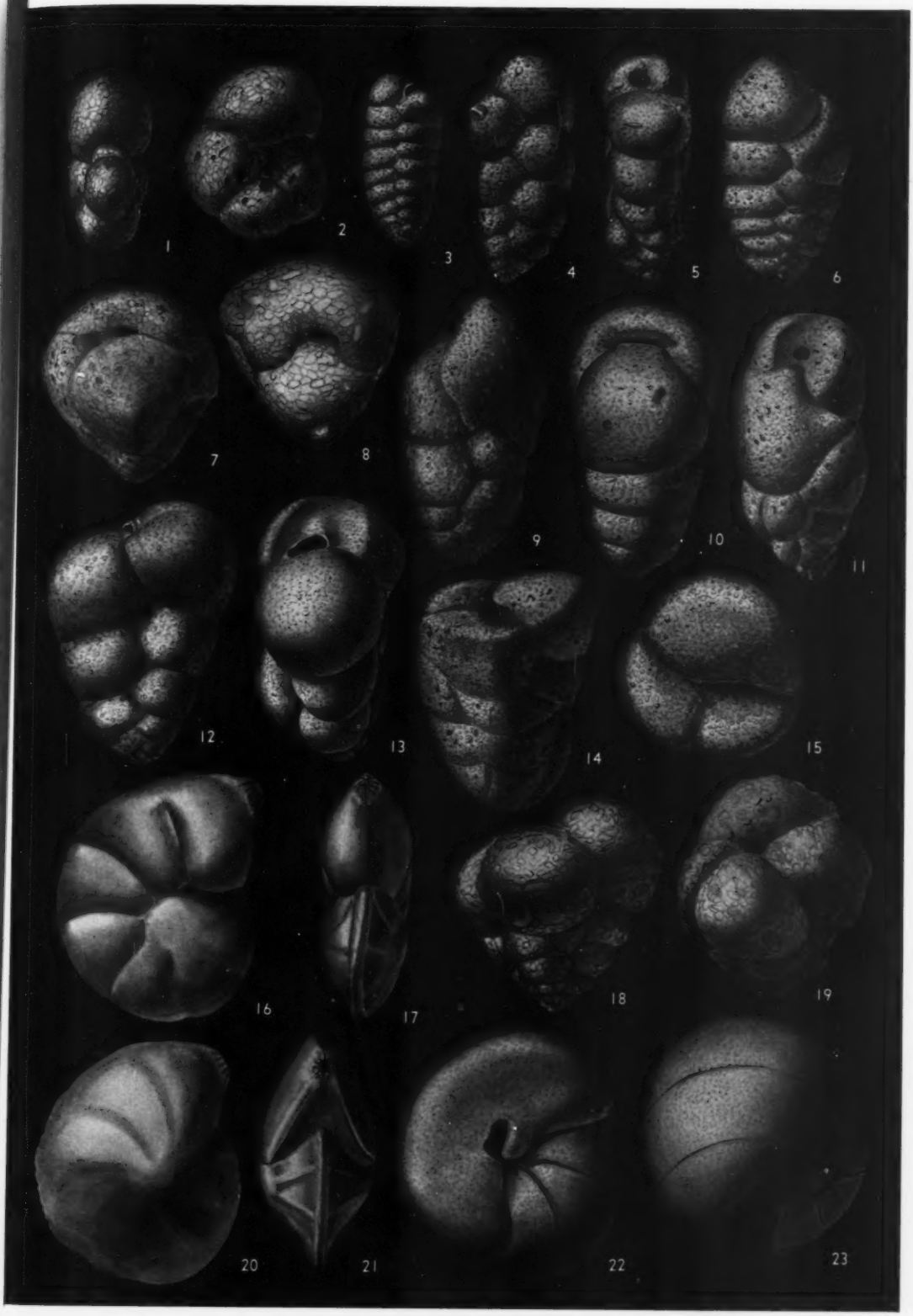
12,13—Gaudryina bulloides n. sp. Holotype. *12*, Side view. *13*, Edge view, showing aperture which is directed toward one side. From the Redbank formation. ×98.

14,15—Marssonella conica n. sp. Holotype. *14*, Side view. *15*, Top view, showing aperture and rounded outline of test. From the Redbank formation. ×141.

16,17,20,21—Robulus navarroensis (Plummer). *16*, Side view, showing development of inflated chambers. *17*, Edge view of same specimen. *20*, Side view, showing more typical development of chambers. *21*, Edge view of same specimen. From the Redbank formation. Figs. *16,17*, ×61. Figs. *20,21*, ×46.

18,19—Trochammina sewellensis n. sp. Holotype. *18*, Side view, showing inflated chambers. *19*, Side view, showing inflated chambers and aperture. From the New Egypt formation. ×185.

22,23—Pernerina redbankensis n. sp. Holotype. *22*, Edge view, showing aperture. *23*, Side view, From the Redbank formation. ×141.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with *Haplophragmoides sewellensis* n. sp. This association apparently indicates unfavorable environmental conditions.

Occurrence.—The species is present in the New Egypt at Contact Creek, at Sewell, and at the NJT 33 locality. It is found in the basal Hornerstown at Contact Creek.

Types.—Holotype (USNM 626441) and paratypes (P 81022 and R 5008) from the New Egypt formation, locality NJT-19.

Family LAGENIDAE
Genus ROBULUS Montfort, 1808
ROBULUS ALABAMENSIS Cushman
Pl. 2, fig. 1

Robulus alabamensis Cushman, 1944, p. 33, pl. 5, fig. 13; Cushman and Todd, 1946, p. 47, pl. 7, fig. 8.

Remarks.—The Hornerstown forms compare well with the type material. The species is characterized by the umbonate close coiled test with a subacute axial periphery and 8–10 chambers in the final whorl. The sutures are slightly curved and not depressed. In general the Hornerstown specimens are larger.

Diameter up to 1.20 mm.

Occurrence.—The species has been recorded from the Paleocene of Alabama and Arkansas. It is a very common species in the Hornerstown at Shingle Run and Crosswicks Creek. It is present in the Vincentown formation.

Types.—Figured hypotype R 5052.

ROBULUS NAVARROENSIS (Plummer) Jennings
Pl. 1, figs. 16,17,20,21

Cristellaria navarroensis Plummer, 1927, p. 39, figs. 4a,b (in text).
Lenticulina navarroensis Plummer, 1931, p. 141.
Robulus navarroensis Jennings, 1936, p. 15, pl. 1, figs. 14a,b; Loetterle, 1937, p. 20, pl. 1, figs. 4a,b; Cushman, 1941, p. 55, pl. 15, fig. 1; Cushman & Todd, 1943, p. 54, pl. 9, fig. 17; Cushman, 1946, p. 51, pl. 16, figs. 6–8; 1950, p. 4, pl. 1, fig. 26.
Cristellaria cultrata Carsey (not Montfort), 1926, p. 38, pl. 6, fig. 3.

Remarks.—The Redbank forms agree with Plummer's figures from the Navarro of Texas in the central umbo, the limbate, slightly raised sutures that fuse with the umbo, the thin keel, and the aperture with a ventral enlarged slit. The Redbank forms vary somewhat in that they exhibit slightly fewer chambers and possess a rather larger umbo. Some of the forms show a less wide thicker keel.

Diameter 1.1 mm. Width 0.4 mm.

Occurrence.—*Robulus navarroensis* is known only from beds of Navarroan age.

EXPLANATION OF PLATE 2

FIG. *1*—*Robulus alabamensis* Cushman. *1*, Side view. From the Hornerstown formation. ×30.
2—*Robulus turbinatus* (Plummer). *2*, Side view. From the Hornerstown formation. ×43.
3,4—*Robulus hornerstownensis* n. sp. Holotype. *3*, Edge view, showing heavy ridge-like keel and prominent median slit. *4*, Side view. From the Hornerstown formation. ×46.
5,6—*Robulus rancocasensis* n. sp. Holotype. *5*, Edge view. *6*, Side view, showing well developed keel. From the Hornerstown formation. ×22.
7,8—*Robulus jenningsi* n. sp. Holotype. *7*, Edge view, showing aperture. *8*, Side view, showing circular umbo and limbate sutures. From the Hornerstown formation. ×30.
9,10—*Planularia dissona* (Plummer). *9*, Side view, showing strongly raised sutures. *10*, Edge view, From the Redbank formation. ×61.
11—*Planularia hookerae* (Jennings). *11*, Side view, showing the heavy raised sutures and the prominent keel. From the Hornerstown formation. ×20.
12,13—*Planularia howelli* n. sp. Holotype. *12*, Side view. *13*, Edge view, showing compressed test and median slit. From the Hornerstown formation. ×46.
14—*Dentalina johnsoni* McLean. *14*, Side view, showing the spiny surface. From the Hornerstown formation. ×61.
15—*Marginulina plummerae* Cushman. *15*, Side view. From the Redbank formation. ×30.
16—*Dentalia angusticostata* Cushman. *16*, Side view. From the Redbank formation. ×30.
17—*Dentalina* cf. *D. basitorta* Cushman. *17*, Side view. From the Redbank formation. ×61.
18—*Dentalia colei* Cushman and Dusenbury. *18*, Side view. From the Hornerstown formation. ×43.
19—*Dentalia plummerae* Cushman. *19*, Side view. From the Hornerstown formation. ×20.
20—*Dentalina virginiana* Cushman. *20*, Side view, showing the delicate longitudinal costae. From the Redbank formation. ×30.
21,22—*Dentalina basiplanata* Cushman. *21,22*, Side views. From the Redbank formation. ×30.

Jennings has recorded it from the Mt. Laurel, Navesink of New Jersey. It is common in the Redbank at Atlantic Highlands and is present at New Egypt.

Types.—Figured hypotypes R 5050 and R 5051.

ROBULUS TURBINATUS (Plummer) Cushman
Pl. 2, fig. 2

Cristellaria turbinata Plummer, 1927, p. 93, pl. 7, fig. 4.

Robulus turbinatus Cushman, 1940, p. 55, pl. 9, fig. 17; Kline, 1943, p. 20, pl. 1, fig. 7; Cushman & Todd, 1946, p. 47, pl. 7, fig. 11

Remarks.—The Hornerstown forms are larger than the measurements given by Plummer. They agree with this species by the much compressed circular test, acute axial periphery with fragile keel, and the fairly large umbo. Other distinguishing characteristics are the very strongly curved sutures and the number of chambers in the final whorl.

Diameter 0.8 to 1.20 mm.

Occurrence.—The species was described from the Midway of Texas. It has been recorded from the Midway of Alabama, Arkansas, and Mississippi. It has been found in the Vincentown formation. It is present in the Hornerstown at Shingle Run and Crosswicks Creek.

Types.—Figured hypotype R 5053.

ROBULUS HORNERSTOWNENSIS n. sp.
Pl. 2, figs. 3,4

Robulus sp. C Beck, 1943, p. 596, pl. 103, figs. 6,7.

Test.—small, close coiled, with a distinct keel, diameter about twice the thickness. Equatorial periphery slightly lobate. *Wall.*—smooth, calcareous. *Chambers.*—five in last whorl, increasing rather rapidly in size as added, slightly inflated. *Sutures.*—slightly curved, flush with surface to somewhat slightly depressed in some specimens. The sutures radiate from the axis of coiling, with a tendency in some forms for the sutures to truncate previous formed ones, so that a small rectangular in shape umbo is formed. *Aperture.*—radiate, produced, with a prominent median slit. Diameter 0.60 to 1.10 mm. Thickness 0.40 to 0.60 mm.

Remarks.—This species was originally figured by Beck as *Robulus* sp. C from the Eocene of Washington. The species differs from *Robulus arkansasana* Cushman and Todd by the presence of a distinct keel, smaller number of chambers, and lack of distinct strongly limbate sutures.

Occurrence.—The species is common in the Hornerstown at Shingle Run and Crosswicks Creek. It is present in the Glendola well (301′–302′) and the Clementon well (210′).

Types.—Holotype (USNM 626442) and paratypes (P 81023 and R5009) from the Hornerstown formation, locality NJT-1.

ROBULUS RANCOCASENSIS n. sp.
Pl. 2, figs. 5,6

Test.—large, close coiled, umbonate, rounded in outline. Axial periphery acutely angled or with a short keel. *Wall.*—calcareous, smooth. *Chambers.*—6–8 in final whorl, increasing uniformly in size. *Sutures.*—limbate, especially near the prominent central umbo, slightly raised to flush with surface, with a tendency in some speciments to be slightly depressed between final chambers. The sutures are tangential to a rounded or somewhat irregular umbo, in some specimens covering the central umbo, and curving gently toward the periphery. *Aperture.*—radiate, sometimes slightly produced, with a median slit. Largest diameter 1.50 to 2.0 mm. occasionally 3.0 mm. Thickness 0.80–1.0 mm.

Remarks.—This species varies according to the degree that a keel is developed and the extent to which the sutures are raised. The species differs from *Robulus midwayensis* (Plummer) and the variety *carinatus* (Plummer) principally by the larger size of the test and fewer number of chambers. It is distinguished from *R. jenningsi* n. sp. by the development of a keel, slightly larger size, smaller number of chambers, raised limbate sutures, and the presence of a median slit.

Occurrence.—This is a very common form in the Hornerstown at Shingle Run and Crosswicks Creek. It is present in the Glendola well (301′–302′). It is a common species in the Vincentown formation.

Types.—Holotype (USNM 626443) and paratypes (P 81024 and R 5010) from the Hornerstown formation, locality NJT-1.

ROBULUS JENNINGSI n. sp.
Pl. 2, figs. 7,8

Test.—large, close coiled, umbonate, rounded in outline. Axial periphery acutely angled, but not keeled. *Wall.*—calcareous, smooth, thick-walled. *Chambers.*—8–10 in final whorl, increasing uniformly in size. *Sutures.*—non limbate to slightly limbate radiating from a circular central umbo, gently curved, flush with the surface. Central umbo even with surface to slightly raised. *Aperture.*—radiate, in all specimens lacking a median slit. Largest diameter 1.2–1.80 mm. Thickness 0.60–0.80 mm.

Remarks.—This species is similar to *Robulus midwayensis* (Plummer). It differs from Plummer's species in the slightly larger size, less limbate or non limbate sutures that are flush with the surface, and fewer number of chambers. It differs from *R. rancocasensis* n. sp. in its smaller size, greater number of chambers, less limbate sutures that are flush with the surface, lack of a peripheral keel, and lack of a median slit.

Occurrence.—This is a very common species in the Hornerstown at Shingle Run and Crosswicks Creek. It is a common species in the Vincentown. It is present in the Glendola well (301′–302′).

Types.—Holotype (USNM 626444) and paratypes (P 81025 and R 5011) from the Hornerstown formation, locality NJT-1.

Genus ASTACOLUS Montfort, 1808
ASTACOLUS JUGLERI (Reuss) Toulmin

Cristellaria jugleri Reuss, 1851, p. 89, pl. 4, figs. 19a,b.
Astacolus jugleri Toulmin, 1941, p. 580, pl. 78, figs. 27,28.

Remarks.—Rare specimens from Shingle Run seem to be the same as the form Toulmin figured as *Astacolus jugleri* (Reuss) from the Salt Mountain limestone of Alabama.

Largest diameter 0.50 mm.

Occurrence.—The species occurs rarely in the Hornerstown at Shingle Run.

Genus PLANULARIA Defrance, 1824
PLANULARIA DISSONA (Plummer) Cushman
Pl. 2, figs. 9,10

Astacolus dissonus Plummer, 1931, p. 145, pl. 11, figs. 17,18, pl. 15, figs. 2–7.
Planularia dissona Cushman, 1941, pl. 68, pl. 16, figs. 15–19; Cushman & Todd, 1943, p. 55, pl. 9, figs. 18a,b; Cushman, 1946, p. 57, pl. 19, figs. 11–18; 1950, p. 4, pl. 2, fig. 5.
Cristellaria reniformis Carsey (not D'Orbigny), 1926, p. 37, pl. 3, fig. 2.

Remarks.—The Redbank species compare well with topotype material and with forms figured by Cushman. They exhibit a moderate amount of variation as do the types figured by Plummer. The strongly compressed test that begins to uncoil in the megalospheric form, thin keel, and raised limbate sutures that become slightly depressed in the adult stages make this species easily distinguishable.

Largest diameter 1.0 mm.

Occurrence.—The species is a good marker for the upper part of the Navarro of Texas and Arkansas. Nine reports its presence throughout the Navesink. It is common in the Redbank at Atlantic Highlands.

Types.—Figured hypotype R 5054.

PLANULARIA HOOKERAE (Jennings)
Pl. 2, fig. 11

Robulus hookerae Jennings, 1936, p. 15, pl. 1, figs. 15a,b.
Planularia crosswicksana McLean, 1951, p. 24, pl. 4, fig. 3.

Remarks.—The species is distinguished by the large, compressed test, keeled periphery, and curved limbate sutures that are raised as ridges in the early stages, especially around the umbonal area. A collection of this species shows these characteristics to be consistent. However, the test may vary somewhat in shape. The immature forms do not possess the compressed test of the adult stage. This species originally was described from the Hornerstown by Jennings. Subsequently, McLean described a single specimen from the Hornerstown as *Planularia crosswicksana*. A comparison of the holotypes and paratypes of *Planularia hookerae* and *Planularia crosswicksana* shows them to be conspecific. McLean, also, has figured a similar species from the Vincentown as *P. crosswicksana* (=*P. hookerae*). His figures do not show the raised ridgelike sutures that are characteristic of this species.

Diameter up to 3.0 mm.

Occurrence.—The species is common in the Hornerstown at Shingle Run.

Types.—Figured hypotype R 5055.

PLANULARIA KLAGSHAMNENSIS Brotzen

Robulus klagshamnensis Brotzen, 1948, p. 41, pl. 7, figs. 1,2.

Remarks.—The Hornerstown forms agree well with Brotzen's specimens from the Swedish Paleocene. The large, strongly compressed test, peripheral keel, numerous chambers, and distinct raised sutures are diagnostic features.

Largest diameter 3.60 mm.

Occurrence.—Brotzen originally described this species from the Paleocene of Sweden. He also records its occurrence in the Lower Paleocene of Denmark. It occurs rarely in the Hornerstown at Shingle Run.

PLANULARIA HOWELLI n. sp.
Pl. 2, figs. 12,13

Test.—small, much compressed, with parallel sides, higher than broad, umbonate. Axial periphery subacute to acute, sometimes with a slight keel. *Wall.*—calcareous, smooth. *Chambers.*—7 in final whorl, increasing rather rapidly in size. *Sutures.*—somewhat limbate, strongly curved, radiating from the central umbo. Flush with surface to slightly depressed in some specimens. *Aperture.*—radiate, with a median slit. Largest diameter 1.0 mm., average 0.60 mm. Thickness 0.30 mm.

Remarks.—This species differs from *Planularia hookerae* Jennings by the small size, lack of a prominent keel, and the lack of any raised ridgelike sutures.

Occurrence.—The species is present in the Vincentown formation. It is common in the Hornerstown at Shingle Run and at Crosswicks Creek.

Types.—Holotype (USNM 626445) and paratypes (P 81026 and R 5012) from the Hornerstown formation, locality NJT-1.

Genus MARGINULINA d'Orbigny, 1826
MARGINULINA PLUMMERAE Cushman
Pl. 2, fig. 15

Marginulina plummerae Cushman, 1937, p. 97, pl. 13, figs. 21–23; Cushman & Todd, 1943, p. 56, p. 56, pl. 10, fig. 2; Cushman, 1946, p. 62, pl. 22, figs. 6–10; 1949, p. 5, pl. 2, fig. 12.
Hemicristellaria ensis Jennings, 1936, p. 17, pl. 2, fig. 3.

Remarks.—The Redbank species are identical with the type material. The compressed test in the early portion gradually becoming less compressed in the adult stages, the ultimate inflated chambers, and the distinct, raised, limbate sutures are diagnostic of this species.

Length up to 1.8 mm.

Occurrence.—This species has only been recorded from beds of late Navarroan age in Texas, Arkansas, and Mississippi. Cushman suggests that it may be an excellent index fossil for the upper part of the Navarro. Jennings figured it from the Mt. Laurel and Nine reports that it is common in the Navesink of New Jersey. It is common in the Redbank of Atlantic Highlands and New Egypt. It has been found in the New Egypt in the Clementon and Glendola wells.

Types.—Figured hypotype R 5057.

MARGINULINA cf. *M. scitula*
Berthelin

Marginulina cf. *M. scitula* Cushman, 1940, p. 56, pl. 9, figs. 21,22; 1951, p. 18, pl. 5, figs. 20,21.
Cristellaria scitula Plummer, 1926, p. 100, pl. 7, fig. 5.

Remarks.—The Hornerstown forms seem to be the same as those figured by Cushman from the Midway of Alabama. The much compressed test and the relatively few uncoiled chambers are characteristic.

Length 1.0 mm. Breadth 0.40 mm.

Occurrence.—This species is rare in the Hornerstown. It is common in the Vincentown formation at the type locality. Elsewhere it is found in the Midway of Alabama, Texas, and Arkansas.

Genus DENTALINA d'Orbigny, 1826
DENTALINA ANGUSTICOSTATA Cushman
Pl. 2, fig. 16

Dentalina angusticostata Cushman, 1938, p. 41, pl. 6, figs. 21,22; 1940, p. 85, pl. 14, figs. 7,8; Cushman & Todd, 1943, p. 57, pl. 10, fig. 10.

Remarks.—Distinguishing characteristics of this species are the elongate, slightly curved, gradually tapering test; the depressed sutures; and the numerous longitudinal costae that continue the length of the test. The Redbank specimens show a slight variation in that the sutures appear to be slightly more depressed and the test slightly narrower.

Length over 2.0 mm. Diameter 0.30 mm.

Occurrence.—The species is found in the Redbank at Atlantic Highlands and New

Egypt. Elsewhere it has been recorded only from the Corsicana Marl of Texas.

Types.—Figured hypotype R 5058.

DENTALINA BASIPLANATA Cushman
Pl. 2, figs. 21,22

Dentalina annulata Cushman, 1931, p. 28, pl. 3, fig. 3.

Dentalina reussi Plummer (not Neugeboren), 1931, p. 3101, p. 151, pl. 11, fig. 5; Sandidge, 1932, p. 274, pl. 42, fig. 10.

Dentalina basiplanata Cushman, 1938, p. 38, pl. 6, figs. 6–8; 1940, p. 82, pl. 14, figs. 1–6; Cushman & Hedberg, 1941, p. 88, pl. 21, fig. 23; Cushman & Todd, 1943, p. 56, pl. 10, fig. 7; Cushman & Deaderick, 1944, p. 333, pl. 51, figs. 17,18; Cushman, 1946, p. 68, pl. 24, figs. 1–6; 1948, p. 251, pl. XXII, fig. 12; 1950, p. 5, pl. 2, fig. 17.

Remarks.—The Redbank forms agree well with the type material. Diagnostic characteristics of this species concern the sutures. The early sutures are oblique and flush with the surface becoming progressively more depressed and more nearly at right angles to the elongate axis. Other features are the early noninflated chambers that become more inflated in the later stages.

Length 1.2 mm. Diameter 0.15 mm.

Occurrence.—Cushman reports that this species is often very abundant in the Corsicana marl, the Kemp clay, and the Arkadelphia marl. It is less common in beds of early Navarroan age and rare in beds of Tayloran age. In New Jersey it occurs in the Redbank at Atlantic Highlands and New Egypt, in the Navesink formation and in the New Egypt in the Clementon well. Nine reports that *D. basiplanata* is common in the Navesink. It is less common in the Redbank.

Types.—Figured hypotype R 5061.

DENTALINA sp. cf. D. basitorta Cushman
Pl. 2, fig. 17

Dentalina basitorta Cuhsman, 1938, p. 37, pl. 6, figs. 4,5; 1940, p. 80, pl. 13, figs. 21,22; 1944, p. 6, pl. 1, fig. 25; Cushman & Deaderick, 1944, p. 332, pl. 51, figs. 9,10; Cushman, 1946, p. 66, pl. 23, figs. 18–20; 1948, p. 251, pl. XXII, fig. 4.

Occurrence.—Cushman described this species from the Selma chalk of Navarroan age in Mississippi. Elsewhere in the Gulf Coast it is restricted to beds of Tayloran age. Cushman regards it as a possibly good index fossil for the Taylor. It is present in the Navesink of New Jersey. It is present in the Redbank at New Egypt.

Types.—Figured specimen R 5059.

DENTALINA COLEI Cushman and and Dusenbury

Dentalina colei Cushman & Dusenbury, 1934, p. 54, pl. 7, figs. 10–12; Parr, 1937–38, p. 76, pl. 1, fig. 8; Toulmin, 1941, p. 584, pl. 79, fig. 12; Cushman, 1944, p. 37, pl. 5, figs. 25–28; Cushman & Todd, 1946, p. 49, pl. 8, fig. 2; Cushman, 1951, p. 19, pl. 6, figs. 8–10.

Vaginulina legumen (Linne) var. *elegans* Cole (not D'Orbigny), 1927, p. 21, pl. 3, figs. 10,11.

Remarks.—This species is characterized by an elongate, slightly curved, tapering test; greatest width near apertural end; and slightly oblique sutures flush with surface. The Hornerstown forms are well within the limits of this species and exhibit no essential differences.

Length up to 4.0 mm. Diameter up to 0.40 mm.

Occurrence.—This species is widely distributed throughout the Midway of the Gulf Coast. It has been recorded from the Eocene of California, Washington, and Australia. It is present in the Salt Mountain limestone of Alabama and the Vincentown of New Jersey. It is common in the Hornerstown at Shingle Run and Crosswicks Creek. It is present in the Glendola well (301′–302′) and the Clementon well (210′).

Types.—Figured hypotype R 5060.

DENTALINA sp. cf. D. fissicostata Gümbel

Remarks.—Fragments of a large Dentalina are present in the Hornerstown. They differ from *Dentalina fissiocostata* by the finer, more numerous, low rounded costae. The chambers are inflated and the sutures depressed in the adult stages. The largest fragments have about 40 costae. Diameter of largest fragment 1.50 mm. Length up to 10.00 mm. Toulmin has figured a similar species from the Salt Mountain limestone and Jennings has recorded the same form as the Gümbel species from the Hornerstown.

DENTALINA JOHNSONI McLean
Pl. 2, fig. 14

Dentalina johnsoni McLean, 1952, p. 6, pl. 2, figs. 4,7.

Remarks.—Distinguishing characteristics of this species are the elongate test, 5 to 6

globular chambers that increase rather rapidly in size, and the numerous continuous longitudinal costae. The Hornerstown forms are identical with paratype material in the U. S. National Museum.

Length up to 1.0 mm. Diameter 0.30 mm.

Occurrence.—This is a common form in the Vincentown. It occurs rarely in the Hornerstown at Shingle Run and at Crosswicks Creek. A single specimen was found in the Glendola well (301′–302′).

Types.—Figured hypotype R 5056.

Dentalina milamensis (Howe)

Nodosaria milamensis Howe, 1939, p. 47, pl. 5, fig. 14.
Dentalina milamensis McLean, 1953, p. 5, figs. 28,29.

Remarks.—Diagnostic features of this species are the elongate, lobate test with initial spine, inflated chambers, depressed sutures, and the longitudinal costae. The costae on the Hornerstown forms are raised to a slightly greater extent. Thus, this lessens somewhat the lobate nature of the test.

Length 1.30 to 1.80 mm. Diameter 0.30 mm.

Occurrence.—The species was described from the Claiborne Cook Mountain formation of Louisiana. It is a common form in the Vincentown formation. In the Hornerstown at Shingle Run it is a common species.

Dentalina plummerae Cushman
Pl. 2, fig. 19

Dentalina plummerae Cushman, 1940, p. 57, pl. 10, figs. 7–9, 19; Kline, 1943, p. 25, pl. 2, fig. 6; Cushman & Todd, 1946, p. 50, pl. 8, fig. 3; Cushman, 1951, p. 20, pl. 6, figs. 11–15.

Remarks.—Diagnostic characteristics of this species are the elongate, slightly curved, tapering test; the pointed initial end of the microspheric stage; subspherical chambers that rapidly increase in size; strongly depressed sutures of adult stages; and the aperture at the end of an elongate tapering neck. McLean has figured a form from the Vincentown as *Dentalina plummerae.* The Vincentown form differs from *D. plummerae* by the greater curvature of the test, the strongly depressed sutures in the early portion, and the lack of any pointed initial end in the microspheric stage. The Hornerstown forms are larger in diameter, but agree in all other aspects.

Length 1.80 mm. Largest diameter 0.50 mm.

Occurrence.—The species is known from the Midway of the Gulf Coast. It occurs mainly in deposits of late Midwayan age. It is not known from lower Midway deposits. It occurs rarely in the Hornerstown at Shingle Run and Crosswicks Creek. A single specimen was found in the Glendola well (301–302′).

Types.—Figured hypotype R 5062.

Dentalina (?) pseudoaculeata n. sp.
Pl. 3, figs. 1,2

Dentalina aculeata Cushman (not D'Orbigny)' 1932, p. 335, pl. 50, fig. 7; Kline, 1943, p. 23' pl. 2, fig. 1; Cushman, 1944, p. 6, pl. 2, fig. 11. 1946, p. 67, pl. 26, figs. 17,18; 1948, p. 251, pl' XXII, fig. 8; Bandy, 1951, p. 499, pl. 73, fig. 4'.

Remarks.—Incomplete specimens in the Redbank and Hornerstown are identical with the species figured by Kline and Cushman as *Dentalina aculeata* d'Orbigny. However d'Orbigny's figure shows a more complete *Dentalina*. The chambers are not separated by slender necks and are more elongate, less inflated than the New Jersey species. The generic position of this species is doubtful, because no complete specimens have been found. The apertural necks lie along the axis of the chamber.

Diameter up to 0.40 mm.

Occurrence.—The species occurs in the Upper Cretaceous of Texas, California, and Maryland. Kline has recorded it from the lower Midway of Mississippi. In New Jersey it is present in the Navesink and Vincentown formations. It is rare in the Redbank at Atlantic Highlands. It occurs commonly in the Hornerstown at Shingle Run and at Crosswicks Creek.

Types.—Holotype (USNM 626446) and paratypes (P 81027 and R 5013) from the Sandy Hook member of the Redbank formation, locality NJK-103. Figured hypotype (R 5063) from the Hornerstown formation, locality NJT-11.

Dentalina soluta Reuss

Dentalina soluta Reuss, 1851, p. 60, pl. 3, fig. 4; Plummer, 1931, p. 150, pl. 11, fig. 14; Toulmin, 1941, p. 587, pl. 79, figs. 23,24.
Nodosaria soluta Plummer, 1927, p. 78, pl. 4, fig. 10; Bermudez, 1938, p. 16; McLean, 1953, p. 6, figs. 26,27.

Remarks.—This species is distinguished

by the greatly inflated chambers, the straight deeply depressed sutures, and the smooth walls. It seems to be a delicate species, that is easily broken. Only fragments of the test were found in the Hornerstown material.

Occurrence.—The species has been recorded from the Upper Cretaceous and Midway of Texas. It is present in the Salt Mountain limestone of Alabama and the Vincentown of New Jersey. Its occurrence is rare in the Hornerstown.

DENTALINA VIRGINIANA Cushman
Pl. 2, fig. 20

Dentalina virginiana Cushman, 1944, p. 22, pl. 4, figs. 8,9; Shifflett, 1948, p. 50, pl. 2, fig. 4.

Test.—free, elongate, very slightly curved, somewhat compressed in transverse section. *Wall.*—calcareous, perforate, covered with thin longitudinal costae, slightly spiral, continuous over the sutures. *Chambers.*—5–6, essentially of same size throughout test, somewhat inflated, proloculum with a short spine. *Sutures.*—distinct, almost at right angles to longitudinal axis, moderately compressed, more so on one side. *Aperture.*—terminal, at one side, radiate, slightly projecting. Length 1.7 mm. Diameter .25 mm.

Remarks.—The Redbank forms agree with this species in the uniform size of chambers, the somewhat spiral longitudinal costae, the depressed sutures, and the short spine at the initial end. However, the Redbank species is larger and has more costae than the type species. It differs from *Dentalina alternata* (Jones) in possessing fewer chambers, in having the sutures depressed more on one side than the other, and the slightly projecting aperture.

Occurrence.—This species has only been recorded from the Tertiary Aquia of Maryland. It is also present in the Paleocene Brightseat formation of Virginia. It is somewhat rare in the Redbank of Atlantic Highlands.

Types.—Figured hypotype R 5064.

DENTALINA CROSSWICKSENSIS n. sp.
Pl. 3, figs. 3,4

Dentalina cf. *D. vertebralis* Cushman, 1935, p. 21, pl. 8, fig. 14 (not fig. 13).

Test.—large, elongate, slightly curved, tapering, greatest width at last few chambers, with an initial spine. *Wall.*—ornamented by numerous, continuous, longitudinal, raised costae, that increase in number with the growth of the test. *Chambers.*—obscure in the earlier portions, inflated in adult stages, slightly longer than broad. *Sutures.*—straight, flush with surface in early portions, much depressed in later portion. *Aperture.*—radiate, produced, at one side of final chamber. Length up to 4.40 mm. Diameter 0.60 mm.

Remarks.—This species differs from *Dentalina pseudo-obliquestriata* (Plummer) by the larger test, straighter costae, and sutures that are even with the surface in early portion of test. This species may be the same as that figured by Cushman as *Dentalina* sp. B. (U. S. Geol. Survey Prof. Paper 232).

Occurrence.—The species was originally figured by Cushman from the Upper Eocene of South Carolina as *Dentalina* cf. *D. vertebralis* (Batch). It is present in the Hornerstown at Shingle Run.

Types.—Holotype (USNM 626447) and paratypes (P 81028 and R 5014) from the Hornerstown formation, locality NJT-1.

DENTALINA RANCOCASENSIS n. sp.
Pl. 3, fig. 7

Nodosaria raphanistrum var. McLean, 1953, p. 6, fig. 5,7.

Test.—large, elongate, arcuate, tapering in the microspheric form, only slightly so in the megalospheric. Megalospheric form shows an initial spine. *Wall.*—ornamented by 10–12 longitudinal costae that are continuous the length of the test except for the last chamber. The last chamber is smooth or shows a faint presence of costae. *Chambers.*—somewhat obscured in early portion, slightly inflated in adult stages. *Sutures.*—flush with surface in initial portion, slightly depressed in later portion, much depressed between last two chambers. *Aperture.*—radiate, slightly produced, toward one side of last chamber. Length up to 6.0 mm. Diameter up to 7.0 mm.

Remarks.—In general shape this species is similar to *Dentalina annloomisae* McLean which was described from the Vincentown formation. It differs from this species by the longitudinal costae that are continuous almost the length of the test. In *D. annloomisae* the costae are restricted to the early portion of the test.

Occurrence.—This species is present in the

Vincentown at the type locality. In the Hornerstown it is present at the Shingle Run and Crosswicks Creek localities.

Types.—Holotype (USNM 626448) and paratypes (P 81029 and R 5015) from the Hornerstown formation, locality NJT-1.

DENTALINA TOULMINI n. sp.
Pl. 3, fig. 5

Test.—elongate, almost straight, with an initial spine. *Wall.*—ornamented with 7–9 heavy, ridgelike, longitudinal costae. The costae run from the initial spine to the penultimate chamber. The final chamber is smooth or shows faint costations. *Chambers.*—about 4 in the megalospheric form; up to 9 in the microspheric form. Inflated in the adult stages, the last one strongly so. *Sutures.*—straight, flush or slightly depressed in early portions, becoming more depressed in adult stages; deeply depressed between last two chambers. *Aperture.*—radiate, much produced, at one side of the last formed chamber. Length of megalospheric form 1.1 mm. Diameter 0.35 mm. Length of microspheric form up to 3.20 mm. Diameter up to 0.55 mm.

Remarks.—This species is similar to *Dentalina milamensis* (Howe). It is distinguished from this species by the less in

EXPLANATION OF PLATE 3

FIGS. *1,2—Dentalina* (?) *pseudoaculeata* n. sp. Holotype. *1*, Side view, showing single chamber and spiny surface. From the Redbank formation. ×46. Hypotype. *2*, Side view. From the Hornerstown formation. ×98.

3,4—Dentalina crosswicksensis n. sp. Holotype. *3*, Side view of megalospheric form. Paratype. *4*, Side view of microspheric form. From the Hornerstown formation. Fig. *3*, ×46. Fig. *4*, ×20.

5—Dentalina toulmini n. sp. Holotype. *5*, Side view. From the Hornerstown formation. ×30.

6—Dentalina sp. *6*, Side view, showing long cylindrical chambers. From the Redbank formation. ×30.

7—Dentalina rancocasensis n. sp. Holotype. *7*, Side view, showing the heavy ridge-like longitudinal costae. From the Hornerstown formation. ×22.

8—Nodosaria spinosa n. sp. Holotype. *8*, Side view, showing surface covered with numerous fine spines. From the Hornerstown formation. ×43.

9—Nodosaria redbankensis n. sp. Holotype. *9*, Side view, showing the delicate longitudinal costae. From the Redbank formation. ×43.

10—Citharina multicostata (Cushman). *10*, Side view. From the Redbank formation. ×30.

11—Vaginulina loeblichi McLean. *11*, Side view. From the Hornerstown formation. ×22.

12—Vaginulina navarroana Cushman. *12*, Side view. From the Redbank formation. ×80.

13—Vaginulina subgracilis Cushman. *13*, Side view, showing characteristic beaded sutures. From the Redbank formation. ×20.

14—Vaginulina crosswicksensis n. sp. Holotype. *14*, Side view, showing the sharp longitudinal costae. From the Hornerstown formation. ×30.

15,16—Vaginulina marginata n. sp. Holotype. *15*, Side view, showing the thickened margin. *16*, Edge view, showing the compressed test and thickened margin. From the Hornerstown formation. ×30.

17—Vaginulinopsis rancocasensis (Jennings). *17*, Side view, showing the heavy raised sutures. From the Hornerstown formation. ×22.

18—Frondicularia midwayensis Cushman. *18*, Side view. From the Hornerstown formation. ×61.

19—Frondicularia sp. *19*, Side view, showing the heavy raised sutures. From the Redbank formation. ×98.

20—Lagena rancocasensis n. sp. Holotype. *20*, Side view, showing the characteristic rim around the neck. From the Hornerstown formation. ×61.

21—Lagena adepta Jennings. *21*, Side view. From the Redbank formation. ×98.

22—Lagena sulcata semiinterrupta (Walker and Jacob). *22*, Side view. From the Redbank formation. ×98.

23—Guttulina hantkeni Cushman and Ozawa. *23*, Side view. From the Hornerstown formation. ×43.

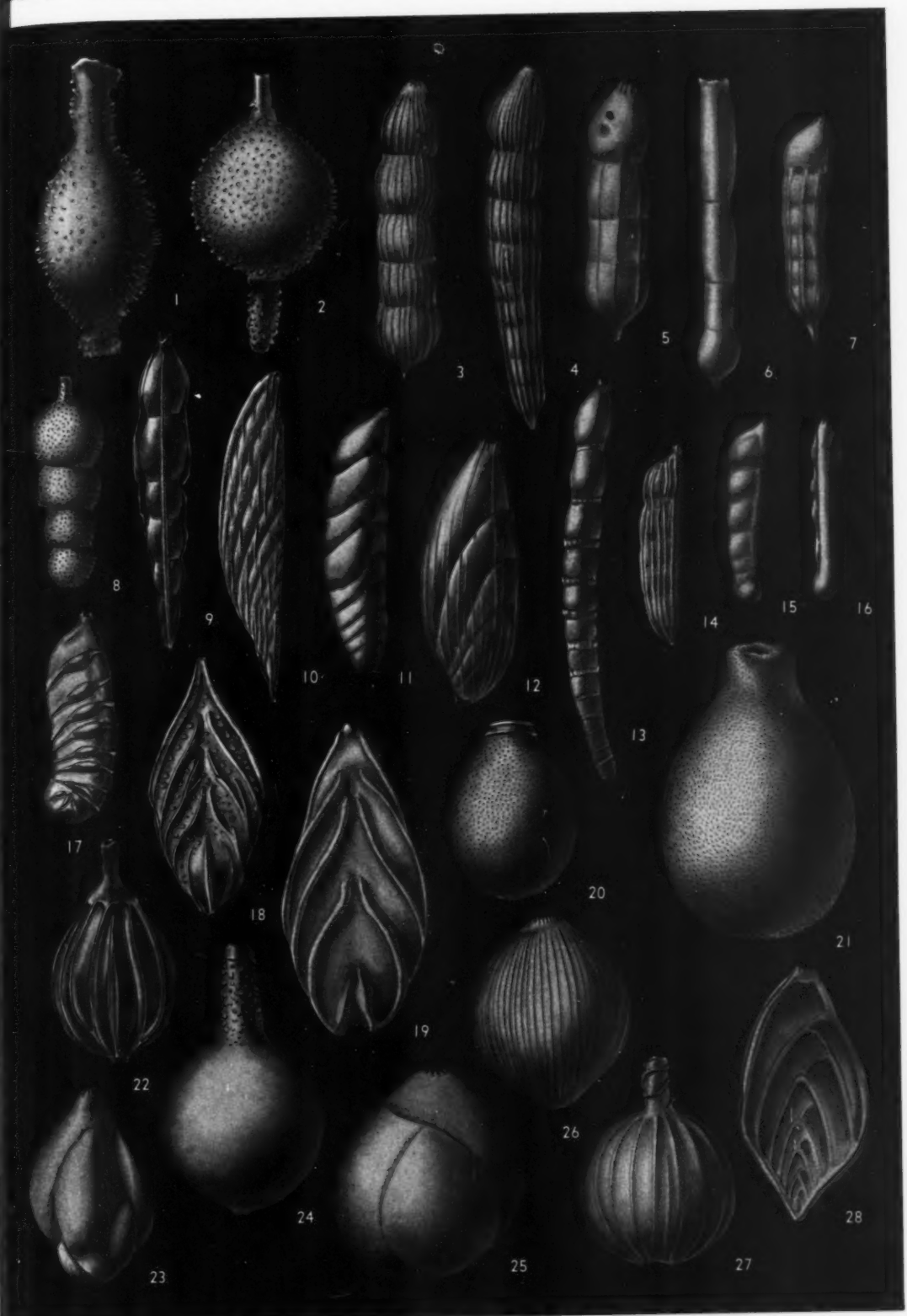
24—Lagena distincta n. sp. Holotype. *24*, Side view, showing characteristic spiny neck with slight lip. From the Hornerstown formation. ×98.

25—Globulina gibba d'Orbigny. *25*, Side view. From the Hornerstown formation. ×61.

26—Rectoglandulina tenuistrata (Franke). *26*, Side view. From the Hornerstown formation. ×61.

27—Lagena pseudocostata n. sp. Holotype. *27*, Side view, showing raised costae and threaded neck. From the Hornerstown formation. ×98.

28—Polymorphina frondea (Cushman). *28*, Side view. From the Hornerstown formation. ×80.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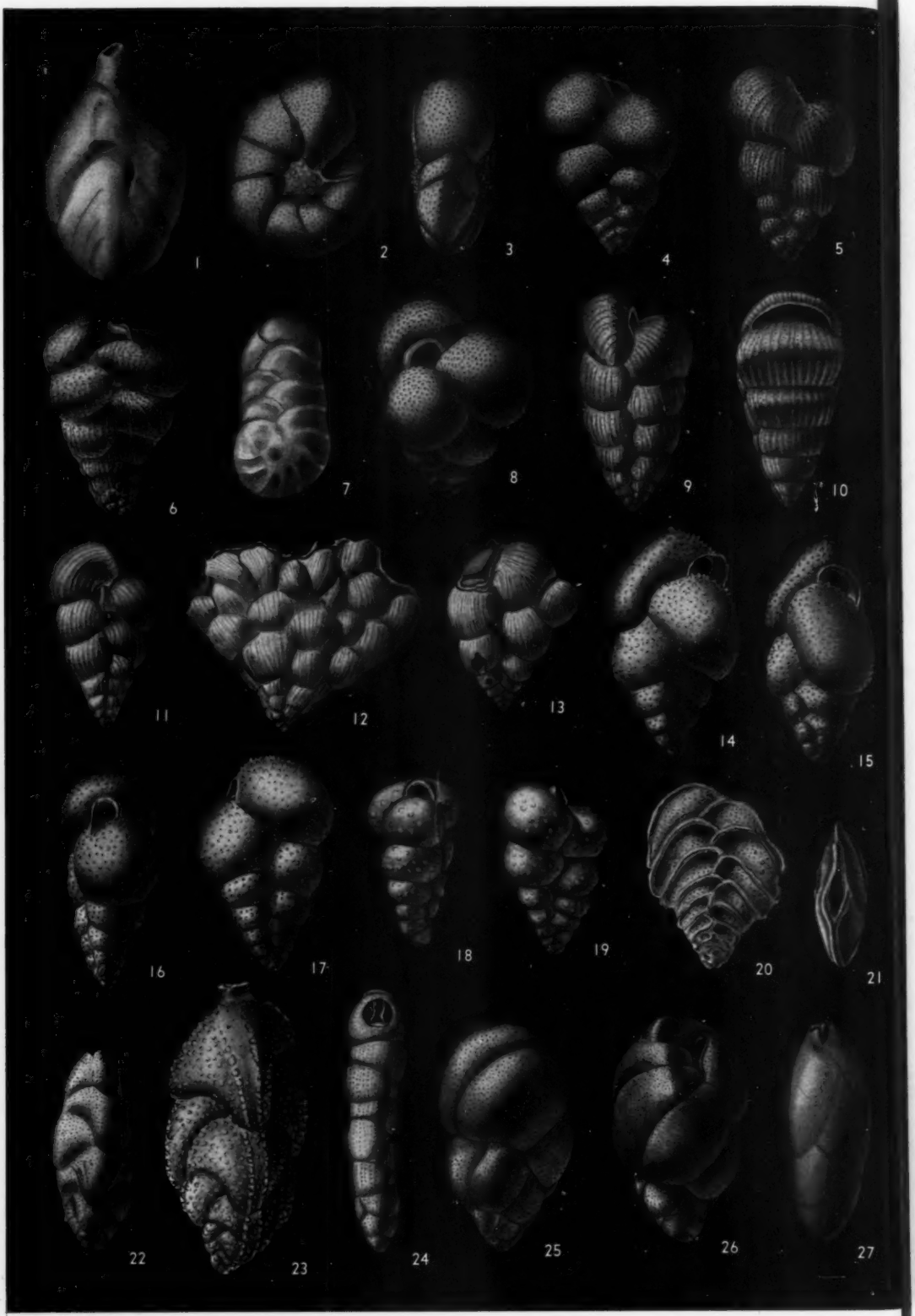
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flated chambers, the heavy ridgelike costae and the nearly smooth last chamber. It differs also by the smaller size of the megalopheric test.

Occurrence.—This species is present in the Vincentown at the type locality. In the Hornerstown it is present at Shingle Run and at Crosswicks Creek.

Types.—Holotype (USNM 626449) and paratypes (P 81030 and R 5016) from the Hornerstown formation, locality NJT-1.

DENTALINA sp.
Pl. 3, fig. 6

Dentalina cf. *D. consobrina* (d'Orbigny) Cushman, 1931, p. 30, pl. 3, figs. 13–15; Cushman & Jarvis, 1932, p. 29, pl. 9, figs. 6,7; Cushman & Hedberg, 1941, p. 89, pl. 21, figs. 30,31; Cushman, 1946, p. 69, pl. 24, figs. 23–27; 1948, p. 252, pl. XXII, figs. 14,15.

Dentalina cf. *pseudofiliformis* Bandy, 1951, p. 500, pl. 73, figs. 8a,b.

Remarks.—Cushman figured this species as *Dentalina* cf. *D. consobrina* d'Orbigny. However, these specimens do not closely resemble d'Orbigny's figure. The initial chamber with a basal spine and the almost cylindrical succeeding chambers that rapidly increase in length are distinct characteristics of the species. The specimens are almost always incomplete.

Diameter 0.15 mm.

Occurrence.—Cushman reports that his specimens occur in beds of late Tayloran age and in the Corsicana marl and Kemp clay of Navarroan age. He also records it in the Upper Cretaceous of Trinidad and Colombia and in the Velasco shale of Mexico. It has been found in well material from Maryland and occurs rarely in the Navesink formation in New Jersey. It is rare in the Redbank of Atlantic Highlands. It is present in the New Egypt in the Clementon and Whitesville wells.

Types.—Figured specimen (R 5017) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Genus NODOSARIA Lamarck, 1812
NODOSARIA AFFINIS Reuss

Nodosaria affinis Reuss, 1845, p. 26, pl. XIII, fig. 16; Cushman, 1946, p. 70, pl. 25, figs. 8–23;

EXPLANATION OF PLATE 4

FIG. *1*—*Polymorphina subrhombica* Reuss. *1*, Side view. From the Hornerstown formation. ×20.
2,3—*Nonion mauricensis* Howe and Ellis. *2*, Side view. *3*, Edge view, showing aperture. From the Hornerstown formation. ×98.
4—*Heterohelix glabrans* (Cushman). *4*, Side view. From the Redbank formation. ×141.
5—*Heterohelix navarroensis* Loeblich. *5*, Side view. from the Redbank formation. ×141.
6—*Heterohelic pulchra* (Brotzen). *6*, Side view. From the Redbank formation. ×141.
7—*Bolivinopsis emmendorferi* (Jennings). *7*, Side view. From the Hornerstown formation. ×141.
8—*Guembelitria cretacea* Cushman. *8*, Oblique view, showing aperture. From the Redbank formation. ×185.
9,10—*Pseudotextularia elegans* (Rzehak). *9*, Side view. *10*, Edge view, showing aperture. From the Redbank formation. ×80.
11—*Pseudoguembelina excolata* (Cushman). *11*, Side view, showing supplementary apertures. From the Redbank formation. ×98.
12—*Planoglobulina acervulinoides* (Egger). *12*, Side view. From the Redbank formation. ×61.
13—*Planoglobulina carseyae* (Plummer). *13*, Side view. From the Redbank formation. ×61.
14,15—*Chiloguembelina crinita* (Glaessner). *14*, Side view. *15*, Edge view, showing asymmetrical aperture with apertural flange. From the Hornerstown formation. ×141.
16,17—*Chiloguembelina midwayensis* (Cushman). *16*, Edge view, showing asymmetrical aperture and apertural flange. *17*, Side view. From the lower Hornerstown formation of the Clementon well. ×185.
18,19—*Woodringina hornerstownensis* n. sp. Holotype. *18*, Edge view, showing asymmetrical aperture. *19*, Side view, showing apertural flange. From the Hornerstown formation. ×185.
20,21—*Bolivinoides compressa* n. sp. Holotype. *20*, Side view, showing raised sutures. *21*, Top view, showing compressed test and aperture. From the Hornerstown formation. ×98.
22—*Pseudouvigerina triangularis* Jennings. *22*, Side view. From the Hornerstown formation. ×46.
23—*Pseudouvigerina seligi* (Cushman). *23*, Side view. From the Redbank formation. ×185.
24—*Siphogenerinoides eleganta* (Plummer). *24*, Side view, showing internal tube. From the Hornerstown formation. ×61.
25,26—*Buliminella fusiforma* Jennings. *25*, Side view. *26*, Front view showing aperture. From the Redbank formation. ×98.
27—*Bulimina quadrata* Plummer. *27*, Side view. From the Redbank formation. ×61.

1951, p. 23, pl. 7, figs. 3–6; McLean, 1953, p. 6, figs. 48,50,51.

Remarks.—Large nodosarians that can be grouped with this species are present in the Hornerstown. They have elongate tests with numerous, approximately 15, longitudinal costae.

Length up to 10.0 mm.

Occurrence.—This species has a wide distribution in the Cretaceous and Tertiary. It is found in the Vincentown formation and is common in the Hornerstown at Shingle Run and Crosswicks Creek.

NODOSARIA LATEJUGATA CAROLINENSIS Cushman

Nodosaria latejugata var. *carolinensis* Cushman, 1933, p. 5, pl. 1, fig. 16; 1935, p. 21, pl. 5, figs. 10–13; Jennings, 1936, p. 177, pl. 29, fig. 10; Toulmin, 1941, p. 588, pl. 79, fig. 28.

Remarks.—Broken specimens of this form are present in the Hornerstown. They are characterized by strongly inflated chambers and depressed sutures, and by 16 to 18 costae. The costae on the Hornerstown forms are strongly raised and twist somewhat as they cross the sutures.

Length 5.0 mm. and larger.

Occurrence.—This form was originally described from the Upper Eocene Cooper marl of South Carolina. It has been recorded from the upper Eocene and Salt Mountain limestone of Alabama. Jennings has previously recorded it from the Hornerstown. It is present at the Shingle Run and Crosswicks Creek localities.

NODOSARIA? cf. N. LONGISCATA D'Orbigny

Nodosaria longiscata Plummer, 1927, p. 82, pl. 4, fig. 17; Cushman, 1940, p. 59, pl. 10, fig. 28; Cushman & Todd, 1946, p. 52, pl. 8, fig. 26.
Nodosarina (*Nodosaria*) *longiscata* Kline, 1943, p. 28, pl. 2, fig. 8.
Nodosaria? cf. *N. longiscata* Cushman, 1951, p. 24, pl. 7, figs. 9,10.

Remarks.—Fragments of an elongate test with slender cylindrical chambers and smooth walls are present in the Hornerstown. The species probably should be given a new name, but sufficient material in the Hornerstown is not available.

Individual chambers up to 1.20 mm.

Occurrence.—Fragments of this very delicate species are found in the Midway of the Gulf Coast. It is present in the Vincentown and in the Hornerstown at Shingle Run and at Crosswicks Creek.

NORDOSARIA SPINOSA n. sp. Pl. 3, fig. 8

Nodosaria aspera Cushman & Jarvis (not Reuss), 1932, p. 35, pl. 11, fig. 5: Cushman & Renz, 1946, p. 29, pl. 4, fig. 30.
Nodosarina (*Nodosaria*) *aspera* Kline, 1943, p. 27, pl. 2, fig. 15.

Test.—elongate, slightly tapering, greatest width in last chamber. *Wall.*—covered by closely set spines. *Chambers.*—distinct, subglobular, inflated, gradually to somewhat rapidly increasing in size. Slightly overlapping. Initial chamber rounded. *Sutures.*—straight, slightly depressed. *Aperture.*—a rounded opening at the end of a long slender cyclindrical neck. Length 0.60 to 1.70 mm. Diameter 0.25 to 0.45 mm.

Remarks.—The species originally was figured by Cushman and Jarvis as *Nodosaria aspera* Reuss from the lower Lizards Springs of Trinidad. It was considered the same species (*N. aspera*) that is characteristic of beds of Tayloran age in the Gulf Coast. It differs from this species in the less tapering test; the more gradual increase in chamber size, the less constricted sutures, and the lack of an initial spine.

Occurrence.—Cushman and Jarvis had considered the Lizard Springs formation to be of Late Cretaceous age. The lower Lizard Springs is now known to contain diagnostic Paleocene Globigerinas and Globorotalias. The only other record of this species is from the upper Midway Porters Creek formation of Mississippi. It is present in the Hornerstown at Shingle Run.

Types.—Holotype (USNM 626450) and paratypes (P 81031 and R 5018) from the Hornerstown formation, locality NJT-1.

NODOSARIA REDBANKENSIS n. sp. Pl. 3, fig. 9

Test.—free, elongate, gradually tapering, greatest width midpoint of last chamber. *Wall.*—calcareous, perforate, ornamented by 5–6, occasionally 8, thin, raised, ragged, very delicate costae, that are continuous the length of the test. *Chambers.*—5–6, inflated, oval shaped, increasing more in length than width as added, initial chamber

with a short spine from which the longitudinal costae begin. *Sutures.*—straight, depressed more so in the adult stages. *Aperture.*—terminal, radiate at the end of a slender neck, to which the costae are attached. Length 1.0 mm. Diameter 0.20 mm.

Remarks.—*Nodosaria redbankensis* n. sp. somewhat resembles *N. navarroana* Cushman. It is distinguished from this form by the gradually tapering test, fewer in number, more inflated chambers, and the more depressed sutures.

Occurrence.—This species has been found only in the Redbank at Atlantic Highlands where it is common.

Types.—Holotype (USNM 626451) and paratypes (P 81032 and R 5019) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Genus SARACENARIA Defrance, 1824
SARACENARIA SARATOGANA Howe and Wallace

Saracenaria italica Cushman (not Defrance), 1932, p. 305, pl. 34, figs. 15,16; Cushman & Todd, 1943, p. 58, pl. 10, fig. 17.
Saracenaria saratogana Howe & Wallace, 1932, p. 41; Cushman, 1946, p. 58, pl. 28, figs. 4–6; 1949, p. 4, pl. 2, fig. 9.

Remarks.—The Redbank specimens compare well with figured forms from the Saratoga chalk of Arkansas. They also agree with specimens in the Cushman collection from the Corsicana marl. Distinguishing features of this species are the tendency to early uncoiling, the blunt angles of the test, and the sutures that become slightly depressed between the last chambers.

Length 1.0 mm.

Occurrence.—The species ranges throughout the Navarro of the Gulf Coast. Nine reports it from the Navesink of New Jersey. It is present in the Redbank at Atlantic Highlands and New Egypt. It also has been found in the New Egypt in the Clementon well.

SARACENARIA cf. S. SUBLATIFRONS (Plummer) Kline

Cristellaria sublatifrons Plummer, 1927, p. 100, pl. 7, fig. 6.
Saracenaria cf. *sublatifrons* Kline, 1943, p. 31, pl. 3, fig. 1.

Remarks.—A few specimens were examined that are close to Plummer's species. They differ principally in their larger size.

Length 1.40 mm.

Occurrence.—The species is rare in the Hornerstown at Shingle Run.

Genus CITHARINA d'Orbigny, 1839
CITHARINA MULTICOSTATA Cushman
Pl. 3, fig. 10

Vaginulina multicostata Cushman, 1930, p. 28, pl. 4, fig. 4; Cushman & Todd, 1943, p. 58, pl. 10, fig. 19; Cushman, 1944, p. 88, pl. 13, fig. 13; Cushman & Deadrick, 1944, p. 334, pl. 52, fig. 3; Cushman, 1946, p. 79, pl. 29, figs. 9–16; 1948, p. 254, pl. XXIII, fig. 5; 1949, p. 6, pl. 2, fig. 24.
Planularia multicostata Bandy, 1951, p. 495, pl. 72, figs. 17a,b.

Remarks.—The Redbank specimens compare well with type material. The elongate, much compressed tests, with parallel sides and straight dorsal edges are typical. Other diagnostic features are the curved, elongate chambers and the numerous fine costae that are in general parallel to the longtitudinal axis of the test.

Length 1.6 mm. Width 0.05 mm.

Occurrence.—Cushman reports that this species is best developed in beds of Navarroan age. There are less typical scattered occurrences below this horizon. Nine records it from the Navesink formation of New Jersey. It is present in the Redbank of Atlantic Highlands, New Egypt, and in the New Egypt in the Glendola and Whitesville wells.

Types.—Figured hypotype R 5065.

CITHARINA PLUMOIDES (Plummer) Brotzen

Vaginulina plumoides Plummer, 1927, p. 113, pl. 6, fig. 6; Cushman, 1940, p. 61, pl. 9, fig. 26; Cushman & Renz, 1942, p. 6, pl. 1, fig. 6; Kline, 1943, p. 33, pl. 3, fig. 6; Cushman & Todd, 1946, p. 55, pl. 9, fig. 20.
Vaginulina strigillata Franke, 1927, p. 45, figs. 4,5.
Citharina plummoides Brotzen, 1948, p. 45, pl. 5, figs. 4,5.

Remarks.—This characteristic species is distinguished by the thin test, strongly oblique sutures, and the fine longitudinal striae. The species has been reported only from beds of Paleocene age.

Length 1.40 mm. and larger.

Occurrence.—This species is restricted to the Paleocene of Texas, Alabama, Arkansas,

and Mississippi. It occurs also in the Paleocene of Trinidad, Denmark, and Sweden. Its occurrence is rare in the Hornerstown at Shingle Run.

Genus VAGINULINA d'Orbigny, 1826
VAGINULINA CRETACEA Plummer

Vaginulina gracilis Plummer var. *cretacea* Plummer, 1927, p. 172, pl. 2, fig. 8; Jennings, 1936, p. 21, pl. 2, fig. 16.
Vaginulina cretacea Cushman, 1936, p. 417, pl. 1, fig. 5; Cushman & Todd, 1943, p. 59, pl. 10, fig. 20; Cushman, 1946, p. 80, pl. 30, figs. 11–14; 1949, p. 6, pl. 3, fig. 1.

Remarks.—This species is easily distinguished by the elongate, slightly compressed, somewhat tapering test and the limbate sutures, the center portions of which are raised.

Occurrence.—*Vaginulina cretacea* is restricted to beds of Navarroan age in the Gulf Coast. Nine reports that it occurs throughout the Navesink. A few broken specimens were found in the Redbank at New Egypt. It also is present in the New Egypt in the Clementon well.

VAGINULINA LOEBLICHI McLean
Pl. 3, fig. 11

Vaginulina loeblichi McLean, 1951, p. 26, pl. 4, figs. 8,9.

Remarks.—The Hornerstown forms are identical with the type material. The species is distinguished by the elongate, compressed test, oblique sutures that are even with the surface, and the smooth wall.

Length 5.10 mm. Thickness 0.40 mm. Width 0.50 mm.

Occurrence.—This species was described from a well in North Carolina and from basal Vincentown material just above the biostrome at Shingle Run, New Jersey. It is a common form in the Hornerstown at Shingle Run.

Types.—Figured hypotype R 5066.

VAGINULINA NAVARROANA Cushman
Pl. 3, fig. 12

Vaginulina navarroana Cushman, 1936, p. 416, pl. 1, fig. 3; Cushman & Hedbeg, 1941, p. 90, pl. 22, fig. 1; Cushman & Todd, 1943, p. 59, pl. 10, fig. 16; Cushman, 1946, p. 80, pl. 29, figs. 17–22; 1949, p. 6, pl. 2, fig. 23.
Planularia navarroana Bandy, 1951, p. 495, pl. 72, figs. 16a,b.

Remarks.—The Redbank specimens are typical of this species and identical with the type material. The compressed test, rounded periphery, curved sutures, projecting aperture, and the somewhat oblique raised costae are diagnostic features of this species.

Length up to 1.2 mm.

Occurrence.—The species was described from the Upper Cretaceous of Georges Bank. It is restricted to beds of late Navarroan age in the Gulf Coast. It has also been recorded from the Upper Cretaceous of Colombia and California. Nine reports its rare occurrence in the Navesink of New Jersey. It is common in the Redbank at Atlantic Highlands. It is present in the New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5067.

VAGINULINA SUBGRACILIS Cushman
Pl. 3, fig. 13

Vaginulina subgracilis Cushman, 1937, p. 103, pl. 15, fig. 13; Cushman & Todd, 1943, p. 59, pl. 10, fig. 22; Cushman, 1946, p. 81, pl. 30, fig. 4.
Vaginulina gracilis Cushman (not Plummer), 1931, p. 34, pl. 4, fig. 11.

Remarks.—The Redbank forms compare well with the holotype of this species. Distinguishing characteristics are the elongate, slightly compressed test, rounded periphery, somewhat inflated chambers that increase gradually in length as added and the strongly thickened limbate sutures that are raised to some extent. The appearance of the thickened sutures is that of small, parallel ridge-like growths that are continuous around the sutures.

Length 2.2 mm.

Occurrence.—This species is restricted to the middle and upper Navarro of Texas and Tennessee. It is common in the Redbank at Atlantic Highlands. It is present in the New Egypt in the Clementon well.

Types.—Figured hypotype R 5068.

VAGINULINA WEBBERVILLENSIS Carsey

Vaginulina webbervillensis Carsey, 1926, p. 39, pl. 2, fig. 7; Cushman, 1930, p. 27, pl. 4, fig. 14; Plummer, 1931, p. 160; Cushman & Todd 1943, p. 59, pl. 10, figs. 21a,b; Todd, 1944, p. 334, pl. 1, figs. 9–18; Cushman, 1946, p. 81, pl. 30, figs. 5–10; 1949, p. 6, pl. 3, fig. 3.

Remarks.—The Redbank forms vary somewhat from the typical species of the

Gulf Coast. The test is not so wide and it exhibits somewhat more costation along the ventral margin. Features in common with the Gulf Coast forms are the initial spine and the sutures that become distinctly curved as they approach the ventral margin.

Occurrence.—A few specimens were found in the Redbank at Atlantic Highlands and New Egypt. In the Gulf Coast this species occurs only in beds equivalent to the upper Navarro. Nine reports its presence in the Navesink.

VAGINULINA CROSSWICKSENSIS n. sp.
Pl. 3, fig. 14

Test.—elongate, compressed, slender, curved, with an initial spine. Test gradually tapering, greatest width near apertural end. *Wall.*—ornamented by numerous longitudinal raised costae that are continuous the length of the test, and multiply as new chambers are added. *Chambers.*—6–8, obscure in early portion of test, last few inflated. *Sutures.*—straight, somewhat obscure, even with surface in initial stages, becoming progressively more compressed in adult stages. Usually conspicuously constricted between last formed chambers. *Aperture.*—marginal, radiate, produced with a short neck. Length 1.1 to 2.0 mm. Width 0.30 to 0.35 mm. Thickness 0.20 to 0.25 mm.

Remarks.—This is a distinctive species. The distinguishing characteristics are the slender, elongate, compressed test ornamented with numerous longitudinal costae. It differs from *Dentalina insulsa* Cushman by the large compressed more tapering test and the marginal aperture with a short neck.

Occurrence.—This is a common species in the Hornerstown at Shingle Run and at Crosswicks Creek. It is common in the Vincentown formation.

Types.—Holotype (USNM 626452) and paratypes (P 81033 and R 5020) from the Hornerstown formation, locality NJT-1.

VAGINULINA MARGINATA n. sp.
Pl. 3, figs. 15,16

Test.—elongate, slender, compressed, slightly curved, gradually tapering with initial end rounded. Greatest width near apertural end. Dorsal edge nearly smooth, narrowly compressed. Ventral side moderately to strongly lobate. *Wall.*—calcareous, smooth. *Chambers.*—6–9, increasing uniformly in size. In the initial stages smooth, in the adult stages becoming increasingly inflated. *Sutures.*—straight to slightly oblique. Flush with surface in the early stages, compressed in later stages. In many specimens the last few sutures are strongly constricted. *Aperture.*—radiate, marginal, produced. Length 1.1–2.0 mm. Width 0.25–0.40 mm. Thickness 0.10–0.35 mm.

Remarks.—The species is somewhat similar to *Dentalina inepta* Cushman. It differs from that species by its larger size, more compressed test, and the presence of a narrowly compressed dorsal margin.

Occurrence.—The species is common in the Hornerstown at Shingle Run and present at the Crosswicks Creek locality. It has been found in the Glendola well (301–302′).

Types.—Holotype (USNM 626453) and paratypes (P 81034 and R 5021) from the Hornerstown formation, locality NJT-1.

Genus VAGINULINOPSIS Silvestri, 1904
VAGINULINOPSIS BRANTLYI (Garrett)

Hemicristellaria brantlyi Garrett, 1941, p. 154, pl. 26, figs. 1–4.

Remarks.—Distinguishing characteristics of this species are the elongate, compressed, tuberculate test and the elevated sutures that are ornamented by numerous tubercles.

Length 1.0 to 3.0 mm. Width 0.45 mm.

Occurrence.—The species was described from the Nanafalia formation of Alabama by Garrett. It is a rare species in the Hornerstown at Shingle Run and at Crosswicks Creek.

VAGINULINOPSIS RANCOCASENSIS
(Jennings) McLean
Pl. 3, fig. 17

Hemicristellaria rancocasensis Jennings, 1936, p. 17, pl. 2, fig. 2.
Vagulinopsis rancocasensis McLean, 1951, p. 24, pl. 4, fig. 10.

Remarks.—This species is identified by the elongate, compressed test, and by the curved, limbate, raised sutures.

Length 1.45 mm. Width 0.55 mm.

Occurrence.—The species was originally described by Jennings from the Hornerstown formation. It is abundant at the

Shingle Run and Crosswicks Creek localities. It is present in the Glendola well (301-302').

Types.—Figured hypotype R 5069.

Genus PALMULA Lea, 1833
PALMULA MCGLAMERYAE Toulmin

Palmula mcglameryae Toulmin, 1941, p. 592, pl. 80, figs. 1–3.

Remarks—This species is characterized by a large compressed test, uninflated chambers, and limbate sutures. The species exhibits considerable variation in ornamentation and test outline. Some of the Hornerstown forms show slightly raised sutures.

Length 3.0 mm. and larger. Breadth 3.0 mm. and larger.

Occurrence.—The species was described from the Salt Mountain limestone of Alabama. It is rare in the Hornerstown at Shingle Run and at Crosswicks Creek.

PALMULA RETICULATA (Reuss) Cushman

Flabellina reticulata Reuss, 1851, p. 30, pl. 1, fig. 22; White, 1928, p. 204, pl. 28, fig. 15; Cushman, 1930, p. 32, pl. 4, figs. 18,19; 1935, p. 87, pl. 13, fig. 19; Jennings, 1936, p. 22, pl. 2, fig. 17.

Frondicularia reticulata Bagg, 1898, p. 50, pl. 3, fig. 6; Weller, 1907, p. 230, pl. 2, fig. 30; Plummer, 1927, p. 39, pl. 2, fig. 5.

Palmula reticulata Cushman, 1940, Key, pl. 20, fig. 9; Cushman & Todd, 1943, p. 60, pl. 10, fig. 23; Cushman, 1946, p. 84, pl. 31, figs. 1–6; 1949, p. 6, pl. 3, figs. 4,5.

Frondicularia cf. *F. interpunctata* Cushman (not Von der Marck), 1926, p. 598, pl. 20, fig. 3.

Remarks.—This species is distinguished by the compressed test, the general outline and the conspicuous reticulated pattern of the surface.

Occurrence.—This form is restricted to the Navarro of the Gulf Coast, except for one occurrence in Texas in material designated as upper Taylor. Bagg and Weller have figured it from the Navesink of New Jersey. Nine reports that it is rare in the Navesink. A single specimen has been found in Redbank outcrop material from New Egypt. It also is present in the New Egypt in the Clementon well.

Genus FRONDICULARIA Defrance, 1824
FRONDICULARIA MIDWAYENSIS Cushman
Pl. 3, fig. 18

Frondicularia midwayensis Cushman, 1940, p. 63, pl. 10, figs. 34,35; 1951, p. 30, pl. 9, fig. 4,5.

Remarks.—The Hornerstown forms are similar to this species in all respects except the general shape and size. They do not become quite as long as the type material, but there is a sufficient number within the lower size limits of this species. Greatest width varies from the approximate midpoint toward the apertural end of the test. Distinguishing characteristics are the much compressed test with small initial spines, the distinct raised sutures, and the finely papillate surface.

Length 1.0 to 1.90 mm. Breadth 0.60 to 0.80 mm.

Occurrence.—The species has been recorded from the Upper Midway of Alabama and the Midway group of Texas. It is common in the Hornerstown at Shingle Run.

Types.—Figured hypotype R 5070.

FRONDICULARIA sp.
Pl. 3, fig. 19

Frondicularia archiaciana Jennings (not D'Orbigny), 1936, p. 22, pl. 2, fig. 18a.

Test.—free, greatly compressed, gently tapering in early portion, becoming somewhat parallel in the later stages; periphery truncate, undulate; about twice as long as broad, maximum width approximate midpoint of test. *Wall.*—calcareous, perforate, thin, smooth. *Chambers.*—distinct, narrow, flattened; not inflated; proloculum oval shaped, inflated. *Sutures.*—slightly raised, almost straight lines that meet at the aperture. *Aperture.*—terminal radiate, at the end of a small neck. Length up to 0.80 mm. Width 0.40 mm.

Remarks.—The proloculum is very fragile and it is usually broken or missing on most specimens. Jennings originally figured this species from the Navesink. Nine has described it as a new species *Frondicularia irregularis* from the Navesink of New Jersey.

Occurrence.—Only a few specimens were found in the Redbank material from Atlantic Highlands. Its also is found in the New Egypt in the Clementon and Glendola wells.

Types.—Figured specimen (R 5022) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Genus RECTOGLANDULINA Loeblich and Tappan, 1955
RECTOGLANDULINA cf. R. CAUDIGERA (Schwager)

Pseudoglandulina cf. *P. caudigera* (Schwager)

Cushman, 1940, p. 60, pl. 11, figs. 2,3; Kline, 1943, p. 29, pl. 2, fig. 17; Cushman, 1951, p. 26, pl. 7, figs. 18,19.

Remarks.—The Hornerstown forms appear to be identical with the species figured by Cushman and Kline. The rapidly tapering test with a small spine is typical.

Length 0.40 mm. Diameter 0.30 mm.

Occurrence.—This species is rare in the Hornerstown at Shingle Run. It is found also in the Vincentown formation.

RECTOGLANDULINA TENUISTRIATA (Franke)
Pl. 3, fig. 26

Glandulina tenuistriata Franke, 1927, p. 18, pl. 1, fig. 25A.
Nodosaria (*Glandulina*) *comata* Plummer (not Batsch), 1927, p. 76 pl. 4, fig. 7.
Pseudoglandulina pygmaea Cushman (not Reuss), 1940, p. 60, pl. 11, fig. 4; Cushman & Todd, 1946, p. 54, pl. 9, figs. 10,11; Cushman, 1946, p. 76, pl. 27, figs. 26,28; McLean, 1953, p. 7, figs. 1,8.
Pseudoglandulina comata Kline (not Batsch), 1943, p. 29, pl. 2, fig. 13.

Remarks.—The species is identified by the short, stout test, large final chamber, and the numerous longitudinal costae that ornament the walls.

Length up to 0.60 mm. Diameter up to 0.45 mm.

Occurrence.—The species has been figured from the Late Cretaceous Arkadelphia marl and the Midway of the Gulf Coast. It is present in the Vincentown formation. In the Hornerstown it is present at Shingle Run.

Types.—Figured hypotype R 5071.

Genus LAGENA Walker and Jacob, 1798
LAGENA ADEPTA Jennings
Pl. 3, fig. 21

Lagena adepta Jennings, 1936, p. 24, pl. 3, fig. 2.

Remarks.—Diagnostic features of this species are the rather large, smooth, globular test and the short, wide apertural neck.

Largest diameter 0.35 mm. Length 0.55 mm.

Occurrence.—*Lagena adepta* was originally described from the Mt. Laurel of New Jersey. Nine reports that it is common in the Navesink. It is present in the Redbank at Atlantic Highlands.

Types.—Figured hypotype R 5072.

LAGENA cf. L. COSTATA (Williamson) Reuss

Lagena cf. *L. costata* Cushman, 1951, p. 32, pl. 9, fig. 13.

Remarks.—A single specimen of this species figured by Cushman was found in the Hornerstown at Shingle Run. The finely costate test with a slender neck is typical.

Diameter 0.25 mm.

Occurrence.—Cushman records this species from the Midway of the Gulf Coast.

LAGENA HEXAGONA (Williamson)

Lagena hexagona Cushman, 1946, p. 95, pl. 39, fig. 16.

Remarks.—A single specimen of a Lagena with hexagonal reticulations was found in the Hornerstown at Shingle Run.

LAGENA MAURICENSIS Howe and Ellis

Lagena mauricensis Howe & Ellis, 1939, p. 51, pl. 6, fig. 13.

Remarks.—The species is identified by the small minutely hispid test with a long neck which is ornamented with a spiral raised thread.

Diameter 0.35 mm.

Occurrence.—This species was described from the Claiborne Cook Mountain formation of Louisiana. It is present in the Vincentown formation at the type locality. In the Hornerstown it is present at Shingle Run.

LAGENA SULCATA SEMIINTERRUPTA
W. Berry
Pl. 3, fig. 22

Lagena sulcata (Walker & Jacob) Parker & Jones var. *semiinterrupta* W. Berry, 1929, p. 5, pl. 3, fig. 19; Cushman, 1931, p. 37, pl. 5, figs. 9–11; Jennings, 1936, p. 23, pl. 2, fig. 23; Kline, 1943, p. 39, pl. 7, figs. 15,16; Cushman, 1946, p. 94, pl. 39, figs. 18–21; 1948, p. 256, pl. 23, fig. 14.

Remarks.—This form is easily distinguished by the costae that divide near the base and continue the length of the test, the slender neck, and the ring that the costae form at the base of the test. Actually this ring is the site of a short slender spine that is usually broken or missing.

Diameter 0.25 mm.

Occurrence.—This form has been recorded from the Selma chalk and Ripley formation of Navarroan age in Tennessee. Jennings reports it from the Mt. Laurel, Navesink of New Jersey. Nine states that its occurrence is rare in the Navesink. The Redbank subspecies is common at Atlantic Highlands and present in the New Egypt area. It has been found in the New Egypt

in the Clementon, Glendola, and Whitesville wells. The subspecies also occurs in the Paleocene Brightseat formation of Virginia.

Types.—Figured hypotype R 5073.

LAGENA RANCOCASENSIS n. sp.
Pl. 3, fig. 20

Lagena clavata Cushman, 1944, p. 23, pl. 4, fig. 12; Shifflett, 1948, p. 52, pl. 2, fig. 8.

Test.—globular to ovate often with a short keel that encircles a small, stout neck. *Wall.*—thick, smooth. *Aperture.*—simple, with a phialine lip. Diameter 0.20 mm. to 0.70 mm.

Remarks.—The species was originally figured by Cushman from the Aquia formation as *Lagena clavata* (d'Orbigny). It differs from that species in the thicker walls, lack of any elongation of the test at the basal end, and a keel which encircles the neck.

Occurrence.—This species is found in the Aquia and Vincentown formations. It also occurs in the Brightseat formation of Maryland. In the Hornerstown it is present at Shingle Run.

Types.—Holotype (USNM 626454) and paratypes (P 81035 and R 5023) from the Hornerstown formation, locality NJT-1.

LAGENA DISTINCTA n. sp.
Pl. 3, fig. 24

Test.—globular with a rather long slender neck, which is ornamented with numerous coarse spines. *Wall.*—smooth. *Aperture.*—simple with a phialine lip. Diameter 0.30 mm.

Remarks.—This species differs from *Lagena rancocasensis* in the lack of any keel that encircles the neck, and in having a rather long slender neck which is ornamented with numerous coarse spines.

Occurrence.—This species is present in the Hornerstown at Shingle Run. It is present also in the Vincentown formation.

Types.—Holotype (USNM 626455) and paratypes (P 81036 and R 5024) from the Hornerstown formation, locality NJT-1.

LAGENA PSEUDOCOSTATA n. sp.
Pl. 3, fig. 27

Lagena costata Cushman (not Williamson), 1935, p. 23, pl. 9, figs. 7,8.

Test.—globular, with numerous sharp costae, and a slender neck which is ornamented with spiral threads. *Aperture.*—

EXPLANATION OF PLATE 5

FIGS. *1,2—Colomia californica mundula* Bandy. *1*, Top view, showing aperture. *2*, Side view, showing conical test. From the Redbank formation. ×185.

3,4—Bulimina referata Jennings. *3*, Side view. *4*, Front view, showing aperture. From the Redbank formation. ×141.

5—Bulimina pseudocacumentata n. sp. Holotype. *5*, Side view, showing longitudinal costae on lower portion of test and aperture. From the Hornerstown formation. ×141.

6,7—Bulimina hornerstownensis n. sp. Holotype. *6*, Front view, showing aperture and smooth walls of test. *7*, Top view, showing aperture. From the Hornerstown formation. ×141.

8—Fissurina oslatus (Shifflett). *8*, Side view. From the Hornerstown formation. ×185.

9—Bulimina arkadelphiana midwayensis Cushman and Parker. *9*, Front view, showing aperture. From the Hornerstown formation. ×98.

10—Virgulina navarroana Cushman. *10*, Side view, showing aperture. From the Redbank formation. ×141.

11—Loxostoma plaitum limbosum Cushman. *11*, Side view. From the Redbank formation. ×61.

12—Angulogerina wilcoxensis (Cushman and Ponton). *12*, Side view. From the Hornerstown formation. ×98.

13,14—Nodosarella irregularis n. sp. Holotype. *13*, Top view, showing aperture. *14*, Side view. From the Hornerstown formation. ×10.

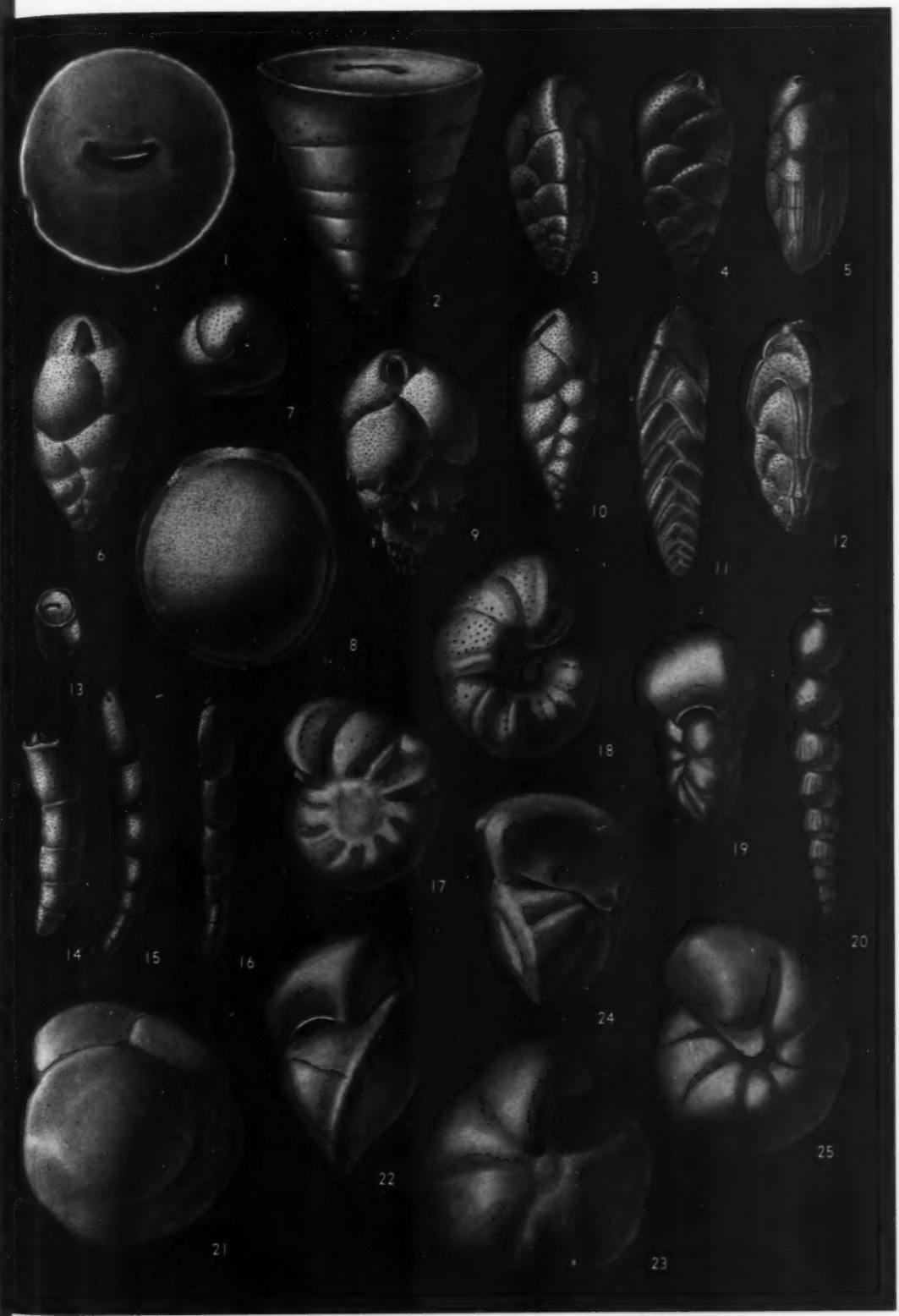
15,16—Nodosarella monmouthensis n. sp. Holotype. *15*, Side view. *16*, Front view, showing aperture. From the Redbank formation. ×43.

17–19—Gavelinella limbata n. sp. Holotype. *17*, Spiral view. *18*, Umbilical view, showing narrow apertural lip and limbate sutures. *19*, Edge view, showing compressed test and extra-umbilical-umbilical aperture. From the Hornerstown formation. ×80.

20—Ellipsonodosaria plummerae Cushman. *20*, Side view. From the Hornerstown formation. ×46.

21–23—Eponides plummerae Cushman. *21*, Spiral view. *22*, Edge view, showing extraumbilical aperture. *23*, Umbilical view. From the Hornerstown formation. ×141.

24,25—Gyroidinoides subangulata (Plummer). *24*, Edge view, showing extraumbilical-umbilical aperture. *25*, Umbilical view, showing apertural lip, which extends over umbilicus, and depressed sutures. From the Hornerstown formation. ×98.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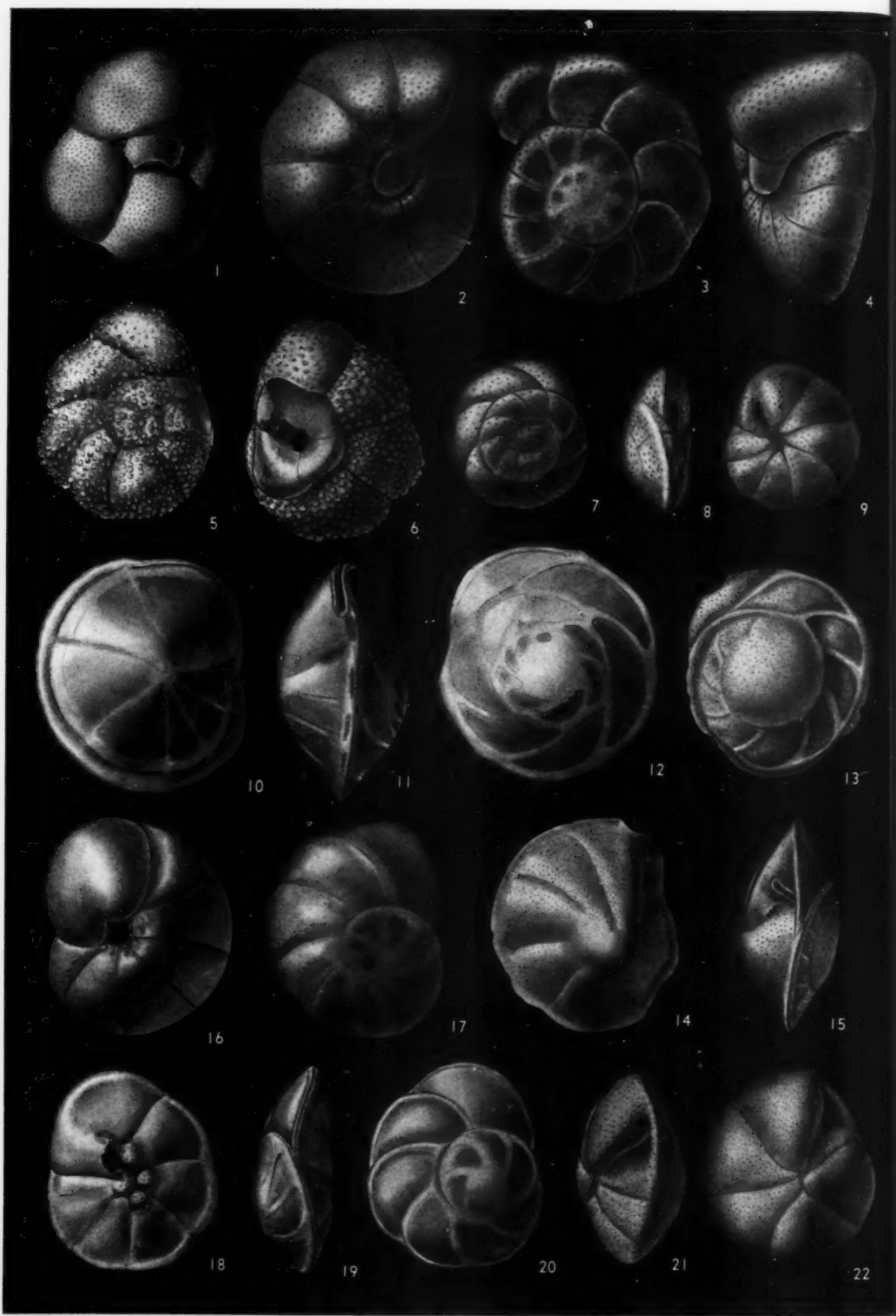
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small circular opening at end of neck. Diameter up to 0.30 mm.

Remarks.—The species was figured by Cushman from the Upper Eocene of South Carolina and Georgia as *Lagena costata* Williamson. It differs from this species in the globular test, numerous sharp costae, and slender neck, which ornamented with spiral threads.

Occurrence.—The species is present in the Hornerstown at Shingle Run.

Types.—Holotype (USNM 626456) and paratypes (P 81037 and R 5025) from the Hornerstown formation, locality NJT-1.

Family POLYMORPHINIDAE
Genus GUTTULINA d'Orbigny, 1839
GUTTULINA HANTKENI Cushman and Ozawa
Pl. 3, fig. 23

Guttulina hantkeni Cushman & Ozawa, 1930, p. 33, pl. 5, figs. 4–6; Cushman & Dusenbury, 1934, p. 60, pl. 8, fig. 5; Cushman & Todd, 1942, p. 34, pl. 6, figs. 11,12; 1946, p. 56, pl. 10, fig. 2; McLean, 1953, p. 8, figs. 14,15.

Remarks.—The paratypes of this species are from the Vincentown formation. The Hornerstown forms compare well with these types.

Length 1.20 to 1.40 mm. Width 0.80 to 1.0 mm.

Occurrence.—The species is known from the Eocene of Hungary and California, the Paleocene of Alabama and Arkansas, and the Vincentown of New Jersey. It is a common form in the Hornerstown at Shingle Run and at Crosswicks Creek. It also is present in the Glendola well (301–302′) and the Clementon well (210′).

Types.—Figured hypotype R 5074.

Genus GLOBULINA d'Orbigny, 1839
GLOBULINA GIBBA d'Orbigny
Pl. 3, fig. 25

Globulina gibba d'Orbigny, 1826, p. 266; Cushman, 1935, p. 25, pl. 9, fig. 18 (See this reference for further synonomy); Toulmin, 1941, p. 594, pl. 80, fig. 9.

Polymorphina gibba Plummer, 1927, p. 122, pl. 6, figs. 8a,b.

Remarks.—Largest diameter 0.60 mm.

Occurrence.—This is a widely distributed species and apparently occurs throughout the Tertiary. It is found in the Hornerstown at Shingle Run and at Crosswicks Creek.

Types.—Figured hypotype R 5075.

GLOBULINA ROTUNDATA (Bornemann) Cushman and Ozawa

Guttulina rotundata Bornemann, 1855, p. 346, pl. 18, fig. 3.

Globulina rotundata Cushman & Ozawa, 1930, p. 86, pl. 21, figs. 3,4; Howe & Wallace, 1932, p. 47, pl. 15, fig. 4; Cushman, 1935, p. 27, pl. 9, figs. 24a–c; 1944, p. 40, pl. 6, figs. 20–22; Cushman & Todd, 1946, p. 56, pl. 10, fig. 4.

Occurrence.—Apparently this species has a wide distribution throughout the Tertiary. It is present in the Hornerstown at the Shingle Run and Crosswicks Creek localities.

EXPLANATION OF PLATE 6

FIG. *1*—*Valvulineria allomorphinoides* (Reuss). *1*, Umbilical view. From the Redbank formation. ×141.

2–4—*Gyroidinodes imitata* n. sp. Holotype. *2*, Umbilical view, showing broad apertural lip, which covers umbilicus. *3*, Spiral view. *4*, Edge view, showing extraumbilical-umbilical aperture. From the Redbank formation. ×185.

5,6—*Lamarckina rugulosa* Plummer. *5*, Spiral view. *6*, Umbilical view. From the Redbank formation. ×61.

7–9—*Pseudoparrella minuta* n. sp. Holotype. *7*, Spiral view. *8*, Edge view, showing interiomarginal-areal aperture. *9*, Umbilical view. From the Hornerstown formation. ×185.

10–12—*Höglundina supracretacea* (ten Dam). *10*, Umbilical view, showing lateromarginal apertures. *11*, Edge view, showing lateromarginal and interio-marginal apertures. *12*, Spiral view. From the Redbank formation. ×80.

13–15—*Parrella convexa* n. sp. Holotype. *13*, Spiral view. *14*, Umbilical view, showing narrow keel. *15*, Edge view, showing biconvex test and areal and interiomarginal apertures. From the Hornerstown formation. ×80.

16,17—*Ceratobulimina cretacea* Cushman and Harris. *16*, Umbilical view, showing umbilical aperture. *17*, Spiral view. From the Redbank formation. ×80.

18–20—*Lamarckina praenaheolensis* n. sp. Holotype. *18*, Umbilical view, showing umbilical aperture. *19*, Edge view. *20*, Spiral view. From the Redbank formation. ×61.

21,22—*Alabamina midwayensis* Brotzen. *21*, Edge view, showing biconvex test and interiomarginal aperture. *22*, Umbilical view. From the Hornerstown formation. ×98.

Genus POLYMORPHINA d'Orbigny, 1826
POLYMORPHINA FRONDEA (Cushman)
Cushman
Pl. 3, fig. 28

Bolivina frondea Cuhsman, 1922, p. 126, pl. 29, fig. 3.
Polymorphina frondea Cushman, 1929, p. 41; Kline, 1943, p. 41, pl. 4, fig. 7; McLean, 1953, pl 8, figs. 11,12,25.

Remarks.—This unique species is identified by the broad compressed test, nearly parallel sides, and smooth walls.

Length 0.80 mm. Width 0.40 mm.

Occurrence.—The species was described from the Lower Oligocene of Mississippi. It also is found in the Paleocene of Mississippi and in the Vincentown formation. It is present in the Hornerstown at Shingle Run.

Types.—Figured hypotype R 5076.

POLYMORPHINA SUBRHOMBICA Reuss
Pl. 4, fig. 1

Polymorphina subrhombica Reuss, 1861, p. 339, pl. 7, fig. 3; Cushman & Ozawa, 1930, p. 114, pl. 30, figs. 1–2; Jennings, 1936, p. 183, pl. 30, fig. 7; Toulmin, 1941, p. 595, pl. 80, fig. 16; McLean, 1953, p. 8, fig. 90.

Remarks.—The species was described from the Vincentown formation by Reuss. The Hornerstown forms are identical with topotype material. The large, broad, compressed test, rounded periphery, and smooth surface are characteristic.

Length 2.40 mm. Breadth 1.60 mm.

Occurrence.—The species is known from the Salt Mountain limestone of Alabama and from the Vincentown and Hornerstown formations of New Jersey. It is present in the Hornerstown at the Shingle Run locality.

Types.—Figured hypotype R 5077.

Family NONIONIDAE
Genus NONION Montfort, 1808
NONION MAURICENSIS Howe and Ellis
Pl. 4, figs. 2,3

Nonion mauricensis Howe & Ellis, 1939, p. 57, pl. 8, figs. 1,2.

Remarks.—This species is easily identified by the small, subcircular test with a slightly lobate periphery, and the cluster of small projecting papillae in the umbilical region.

Diameter 0.30 mm.

Occurrence.—The species was described from the Cook Mountain formation of Louisiana. It is also found in the lower Midwayan Brightseat formation of Maryland, and in the Hornerstown at the Shingle Run locality.

Types.—Figured hypotype R 5078.

Genus NONIONELLA Cushman, 1926
NONIONELLA ANSATA Cushman

Nonionella ansata Cushman, 1938, p. 44, pl. 7, fig. 17; 1946, p. 101, pl. 44, fig. 1; 1950, p. 7, pl. 3, fig. 18.
Nonionella cretacea Jennings (not Cushman), 1936, p. 25, pl. 3, figs. 3a,b.

Remarks.—The Redbank forms are identical with type material. Diagnostic characteristics that aid in identification are the compressed, somewhat broad test, chambers that rapidly increase in length, and strongly curved sutures. Jennings recorded this species from the Mt. Laurel as *Nonionella cretacea*. However, *N. cretacea* is a smaller, more compressed form.

Occurrence.—*Nonionella ansata* is known in the Gulf Coast only from beds of late Navarroan age. It has been reported from the Navesink formation. It is present in the Redbank at Atlantic Highlands, and New Egypt. It has been found also in the New Egypt in the Clementon and Whitesville wells.

Family HETEROHELICIDAE
Genus HETEROHELIX Ehrenberg, 1843
HETEROHELIX GLABRANS (Cushman)
Pl. 4, fig. 4

Gümbelina tessera Cushman, 1936, p. 418; pl. 1, figs. 9a,b.
Gümbelina glabrans Cushman, 1938, p. 15, pl. 3, figs. 1,2; Cushman & Hedberg, 1941, p. 92, pl. 22, fig. 16; Cushman & Todd, 1943, p. 64, pl. 11, fig. 14; Cushman, 1946, p. 109, pl. 46, figs. 17,18.

Remarks.—Diagnostic features of this species are the compressed tapering test, compressed chambers, and the somewhat roughened wall of the early portion that becomes smooth and polished in the adult stages.

Length 0.40 mm.

Occurrence.—This species is characteristic of the upper Navarro of the Gulf Coast. It has been reported from the Navesink formation of New Jersey. It occurs rarely in the

Redbank at Atlantic Highlands and New Egypt; and in the New Egypt of the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5079.

HETEROHELIX NAVARROENSIS Loeblich
Pl. 4, fig. 5

Heterohelix navarroensis Loeblich, 1951, p. 107, pl. 12, figs. 1–3b, text fig. 1; Gallitelli, 1957, p. 137, pl. 31, figs. 5–11.

Remarks.—The species is identified by the small size of the test, rapid increase in chamber size, and the faintly striate surface.

Length 0.25 mm. Width 0.15 mm.

Occurrence.—The species was described by Loeblich from the Kemp clay of Texas. He also reported its occurrence in basal Navarro strata. It occurs in the Navesink formation of New Jersey. It is a common species in the Redbank at Atlantic Highlands and New Egypt. It also is present in the New Egypt in the Whitesville, Glendola, and Clementon wells.

Types.—Figured hypotype R 5080.

HETEROHELIX PULCHRA (Brotzen) Gallitelli
Pl. 4, fig. 6

Gümbelina pulchra Brotzen, 1936, p. 121, pl. IX, figs. 2,3.
Heterohelix pulchra Gallitelli, 1957, p. 137, pl. 31, fig. 20.
Gümbelina tessera Cushman, 1932, p. 338, pl. 51; figs. 4,5; Jennings, 1936, p. 27, pl. 3, figs. 10a,b.
Gümbelina pseudotessera Cushman, 1938, pl. 14, pl. 2, figs. 19–21; 1944, p. 91, pl. 14, fig. 5; 1946, p. 106, pl. 45, figs. 16–20.

Remarks.—The distinguishing characteristics of this species are the compressed, tapering test, broad chambers, depressed curved sutures, and the aperture with a slight lip and lateral flanges.

Length 0.30 to 0.38 mm.

Occurrence.—This species ranges through the Austin and Taylor of the Gulf Coast. Jennings has recorded it from Navesink formation of New Jersey. In Trinidad the species ranges from the Turonian through the Maestrichtian. It occurs rarely in the Redbank at Atlantic Highlands and New Egypt, and in the New Egypt in the Glendola, Whitesville, and Clementon wells.

Types.—Figured hypotype R 5081.

Genus BOLIVINOPSIS Yakovlev, 1891

BOLIVINOPSIS EMMENDORFERI (Jennings)
Pl. 4, fig. 7

Spiroplectoides emmendorferi Jennings, 1936, p. 26, pl. 3, fig. 8.
Spirobolivina scanica Hofker (not Brotzen), 1955, p. 8, pl. 5.

Remarks.—This species is easily identified by the minute compressed test and the short biserial section. It can be distinguished from *Bolivinopsis scanica* Brotzen by its smaller size, more compressed test, and shorter biserial section.

Length 0.21 mm. Width 0.10 mm.

Occurrence.—The species was originally described from the Hornerstown formation by Jennings. It also occurs in the overlying Vincetown formation. It is a common form in the Hornerstown at the Shingle Run and Crosswicks Creek localities. It is present in the Glendola well (301–302′) and Clementon well (210′).

Types.—Figured hypotype R 5082.

BOLIVINOPSIS ROSULA (Ehrenberg) Macfadyen

Spiroplecta rosula Ehrenberg, 1854, pl. 32, fig. 26.
Spiroplectoides rosula (Ehrenberg) Cushman, 1927, p. 62, pl. 13, figs. 9a,b; 1927, p. 114, pl. 23, figs. 6,7; 1931, p. 44, pl. 7, fig. 9; 1934, p. 38, pl. 6, figs. 10–13.
Bolivinopsis rosula Macfayden, 1933, p. 141; Cushman & Todd, 1943, p. 64, pl. 11, fig. 10; Cushman, 1944, p. 10, pl. 2, fig. 17; Cushman & Deaderick, 1944, p. 336, pl. 53, fig. 1; Cushman, 1946, p. 101, pl. 44, figs. 4–8; 1948, p. 257, pl. XXIV, figs. 5,6; 1950, p. 7, pl. 3, fig. 20.

Remarks.—This species is easily distinguished by the elongate, slender, compressed test; the close, planispirally coiled initial end; and the longer than broad chambers of the biserial portion.

Occurrence.—In the Gulf Coast this species ranges from the Austin to the Navarro. It is present in the Upper Cretaceous of Maryland. It is present in the Redbank and Navesink formations.

Genus GUEMBELITRIA Cushman, 1933

GUEMBELITRIA CRETACEA Cushman
Pl. 4, fig. 8

Gümbelitria cretacea Cushman, 1933, p. 37, pl. 4, figs. 12a,b; 1936, p. 418, pl. 1, figs. 12a,b; Jennings, 1936, p. 28, pl. 3, fig. 12; Cushman, 1938, p. 19, pl. 3, figs. 14a,b; Cushman & Hedberg,

1941, p. 91, pl. 22, fig. 17; Cushman & Todd, 1943, p. 65, pl. 11, fig. 16; Cushman, 1946, p. 103, pl. 44, fig. 14; 1948, p. 259, pl. XXIV, fig. 12; Gallitelli, 1957, p. 136, pl. 31, figs. 1a,b.

Remarks.—The Redbank forms compare well with the type material. The spherical chambers, strongly depressed sutures, and rather large aperture are diagnostic of this species. The aperture of the Redbank species is bordered by a narrow lip.

Length 0.20 mm.

Occurrence.—This species is restricted to the Navarro of the Gulf Coast. It has been recorded from the Upper Cretaceous of Maryland and Colombia. Jennings reported it from the Mt. Laurel and Navesink formations of New Jersey. It is common in the Redbank at Atlantic Highlands and New Egypt; and in the lower New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5083.

Genus PSEUDOTEXTULARIA Rzehak, 1886

PSEUDOTEXTULARIA ELEGANS (Rzehak) Gallitelli

Pl. 4, figs. 9,10

Cuneolina elegans Rzehak 1891, p. 2.
Gümbelina elegans White, 1929, p. 34, pl. 4, fig. 8.
Pseudotextularia elegans Gallitelli, 1957, p. 138, pl. 33, fig. 6.
Pseudotextularia a Plummer, 1927, p. 35, pl. 2, fig. 1.
Gümbelina plummerae Loetterle, 1937, p. 33, pl. 5, figs. 1,2; Cushman, 1938, p. 15, pl. 3, figs. 3–5; Cole, 1938, p. 34 (list), pl. 3, fig. 9; Cushman, 1944, p. 90, pl. 14, fig. 3; 1946, p. 104, pl. 45, figs. 1–3; 1948, p. 257, pl. XXIV, fig. 2; 1950, p. 7, pl. 3, figs. 21,22; Said & Kenawy, 1956, p. 139, pl. 3, fig. 33.

Remarks.—Distinguishing features of this species are the tapering test, chambers that rapidly expand in width, depressed sutures, longitudinal costae, and the aperture with a low broad arch.

Length 0.40 to 0.50 mm. Breadth 0.20 to 0.30 mm.

Occurrence.—The species is widely distributed throughout the Upper Cretaceous of the Gulf Coast. It has been recorded from the Navesink formation by Nine. It is present in the Redbank at Atlantic Highlands and New Egypt. Its occurrence is rare in the lower New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5084.

Genus PSEUDOGUEMBELINA Bronnimann and Brown, 1953

PSEUDOGUEMBELINA EXCOLATA (Cushman) Bronnimann and Brown

Pl. 4, fig. 11

Guembelina excolata Cushman, 1926, p. 20, pl. 2, fig. 9; Cushman, 1927, p. 157, pl. 28, fig. 13.
Gümbelina excolata White, 1929, p. 34, pl. 4, fig. 7a,b; Cushman, 1938, p. 17, pl. 3, figs. 11a,b; Cushman & Hedberg, 1941, p. 92, pl. 22, fig. 14; Cushman, 1946, p. 108, pl. 46, figs. 16a,b; LeRoy, 1953, p. 34, pl. 7, figs. 24,25; Hamilton, 1953, p. 234, pl. 30, fig. 11.
Pseudogümbelina excolata Bronnimann & Brown, 1953, p. 153, text figs. 1–4; Said & Kenawy, 1956, p. 139, pl. 3, fig. 36.
Textularia costata Carsey, 1926, p. 26, pl. 1, fig. 4.

Remarks.—This species is easily identified by the tapering biserial test, compressed adult chambers that are ornamented by relatively strong costae, and the characteristic primary and accessory apertures.

Diameter 0.40 mm.

Occurrence.—The species has a wide distribution. It has been recorded from the Upper Cretaceous of the United States, Mexico, Colombia, Cuba, Egypt, Israel, and the Mid Pacific. It is found in beds of Campanian and Maestrichtian age in Trinidad. It is present in the Navesink formation of New Jersey. It is rare in the Redbank at Atlantic Highlands and New Egypt; and in the lower New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5085.

Genus PLANOGLOBULINA Cushman, 1927

PLANOGLOBULINA ACERVULINOIDES (Egger) Cushman

Pl. 4, fig. 12

Gümbelina acervulinoides Egger, 1899, p. 36, pl. 14, figs. 17,18, 20–22.
Planglobulina acervulinoides (Egger) Cushman, 1927, p. 158, pl. 27, fig. 3; White, 1929, p. 33, pl. 4, fig. 6; Cushman, 1938, p. 23, pl. 4, figs. 5–8; 1946, p. 111, pl. 47, figs. 12–15; 1950, p. 8, pl. 3, fig. 27.

Remarks.—The much compressed test, subglobular chambers, depressed sutures, and longitudinal costae are diagnostic of this species.

Length 0.60 mm. Breadth 0.60 mm.

Occurrence.—The species is characteristically developed in the Mendez shale of Mexico. Cushman has recorded it from the Navarro of Alabama and the Arkadelphia marl of Arkansas. It is common in the Navesink formation of New Jersey. The

species is present in the Redbank at Atlantic Highlands. One specimen was found in the lower New Egypt of the Glendola well.

Types.—Figured hypotype R 5086.

PLANOGLOBULINA CARSEYAE (Plummer)
Gallitelli
Pl. 4, fig. 13

Ventilabrella carseyae Plummer, 1931, p. 178, pl. 9, figs. 7–10; Jennings, 1936, p. 28, pl. 3, figs. 13a,b; Cushman, 1938, p. 26, pl. 4, figs. 20–24; Cole, 1938, p. 34, pl. 3, figs. 7, 8; Cushman & Hedberg, 1941, p. 93, pl. 22, figs. 18a,b; Cushman & Todd, 1943, p. 65, pl. 11, fig. 18; Cushman, 1946, p. 112, pl. 48, figs. 1–5.

Planoglobulina carseyae Gallitelli, 1957, p. 141, pl. 32, fig. 13.

Remarks.—This species is identified by the almost biserial test that develops additional chambers in the adult stages, the globular chambers, strongly depressed sutures, thin costate walls, and large primary aperture with supplementary apertures.

Length 0.45 to 0.58 mm.

Occurrence.—This species is characteristic of the upper Navarro of the Gulf Coast. In Trinidad it ranges through beds of upper Campanian and Maestrichtian age. Jennings has reported it from the Mt. Laurel and Navesink formations of New Jersey. It is common in the Navesink. In the Redbank it is common at Atlantic Highlands, and present at New Egypt. The species is present in the lower New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5087.

Genus CHILOGUEMBELINA Loeblich and Tappan, 1956

CHILOGUEMBELINA CRINITA (Glaessner)
Pl. 4, figs. 14,15

Gümbelina crinita Glaessner, 1937, p. 383, pl. IV, figs. 34a,b.

Chilogümbelina crinita Loeblich & Tappan, 1957, pl. 178, pl. 49, fig. 1, pl. 51, figs. 1–3, pl. 56, fig. 1, pl. 60, fig. 6, pl. 62, fig. 1.

Gümbelina wilcoxensis Toulmin, 1951, p. 597, pl. 80, fig. 24; Shifflett, 1948, p. 60, pl. 3, fig. 8.

Remarks.—Distinguishing features of this species are the small, compressed, rapidly tapering test, depressed sutures, and the ovate, overlapping chambers.

With 0.15 to 0.25 mm. Length 0.25 to 0.30 mm.

Occurrence.—On the Atlantic and Gulf Coastal Plains this species occurs in the Hornerstown, Vincentown, Aquia, Salt Mountain, Nanafalia, and Velasco formations. In the Hornerstown it occurs at Shingle Run, Crosswicks Creek, and Permutit pit, Birmingham. It has been found in the Glendola well (301–313′) and Whitesville well (210–225′). It also is present in the Noxontown fauna of Delaware.

Types.—Figured hypotype R 5088.

CHILOGUEMBELINA MIDWAYENSIS (Cushman)
Pl. 4, figs. 16,17

Gumbelina midwayensis Cushman, p. 65, pl. 11, fig. 15.

Chilogümbelina midwayensis Loeblich & Tappan, 1957, p. 179, pl. 43, fig. 7, pl. 45, fig. 9, pl. 41, fig. 3.

Remarks.—The species is identified by the small, elongate, rapidly tapering test, depressed sutures, and the somewhat overlapping, globular chambers.

Length 0.25 to 0.30 mm. Width 0.15 to 0.20 mm.

Occurrence.—This species occurs in the Paleocene of the Gulf Coast. It has been found in the basal Hornerstown (210′) of the Clementon well. The species also is present in the Glendola well (312–313′) and Whitesville (220–281′).

Types.—Figured hypotype R 5089.

Genus WOODRINGINA Loeblich and Tappan, 1957

WOODRINGINA HORNERSTOWNENSIS n. sp.
Pl. 4, figs. 18,19

Test.—small, elongate, slightly twisted, rather rapidly tapering, about twice as long as broad. Initial end consists of whorl of 3 chambers, rest of test consists of biserial arrangement of chambers. *Wall.*—smooth, surface of last two chambers may be finely spinose, especially near the aperture. *Chambers.*—numerous, somewhat inflated, wider than high, increasing more rapidly in width than height as added. *Sutures.*—distinctly depressed, nearly at right angles to axis of test. *Aperture.*—a low arch at one side of final chamber, directed inward, with a small lateral flange along the periphery. Length 0.20 to 0.30 mm. Thickness 0.10 to 0.15 mm. Width 0.10 to 0.15 mm.

Remarks.—This species is characterized by the elongate tapering test, almost straight sutures, and the wide chambers.

Occurrence.—The species is present at the Shingle Run and Crosswicks Creek localities. It has been observed in the Glendola well (312–313′). It also occurs in the

Noxontown assemblage of Delaware.

Types.—Holotype (USNM 626457) and paratypes (P 81038 and R 5026) from the Hornerstown formation, locality NJT-11.

Genus BOLIVINOIDES Cushman, 1927
BOLIVINOIDES COMPRESSA n. sp.
Pl. 4, figs. 20,21

Test.—small, biserial, much compressed, rapidly expanding from a subacute initial end. Greatest width near midpoint of test at base of last formed chambers. *Wall.*—calcareous, smooth. *Chambers.*—elongate, strongly compressed, increasing rapidly in size as added. Peripheral edge slightly carinate. The last formed chambers frequently extend beyond the peripheral edge of the previous chambers and protrude as small ledges. *Sutures.*—curved downward, raised considerably as thin keel like ridges, especially at center of test where the chambers overlap. The raised sutural ridge runs down the center of the test in a zig-zag fashion. *Aperture.*—a small opening at the base of the last formed chamber. Length 0.30 mm. Width 0.23 mm. Thickness 0.07 mm.

Remarks.—This species resembles *Bolivinoides trinitatensis* Cushman and Jarvis. It differs from that species by its smaller size, the shape of the test, and the more delicate ornamentation of the test.

Occurrence.—The species is present in the Hornerstown at Shingle Run and Crosswicks Creek. It is present in the Glendola well (301–302′) and the Clementon well (210′).

Types.—Holotype (USMN 626458) and paratypes (P 81039 and R 5027) from the Hornerstown formation, locality NJT-11.

Genus TAPPANINA Gallitelli, 1956
TAPPANINA SELMENSIS (Cushman)

Bolivinita selmensis Cushman, 1933, p. 58, pl. 7, figs. 3,4; 1936, p. 419, pl. 1, figs. 7a,b; 1946, p. 114, pl. 49, figs. 1 (not fig. 2); Brotzen, 1948, p. 56, pl. 9, fig. 7, text fig. 16.
Bolivina selmensis Hofker, 1955, p. 8, pl. IV.
Bolivinita crawfordensis Jennings, 1936, p. 28, pl. 3, fig. 14.
Tappanina selmensis Gallitelli, 1956, p. 37, pl. 7, figs. 3,4.
Eovigerina excavata Cushman, 1940, p. 66, pl. 11, fig. 18.

Remarks.—The species is characterized by the minute biserial test, broad somewhat concave chamber faces, and strong horizontal and lateral carinae.

Length 0.30 mm.

Occurrence.—This species has a wide range and distribution. It has been recorded from beds of Late Cretaceous age through the Paleocene. In New Jersey it is present in the Navesink and Vincentown formations. It is present in the Redbank formation at Atlantic Highlands and at New Egypt, and in the Hornerstown formation at Shingle Run and Crosswicks Creek. It is found in the New Egypt and Hornerstown intervals in the Glendola, Clementon, and Whitesville wells.

Genus PSEUDOUVIGERINA Cushman, 1927
PSEUDOUVIGERINA SELIGI (Cushman)
Cushman and Todd
Pl. 4, fig. 23

Uvigerina seligi Cushman, 1925, p. 1, pl. 4, figs. 1a–c; Plummer, 1931, p. 186, pl. 14, fig. 10; Jennings, 1936, p. 32, pl. 3, fig. 24.
Pseudovigerina seligi Cushman & Todd, 1943, p. 65, pl. 11, fig. 19; Cushman, 1946, p. 117; pl. 49, figs. 21–24; 1948, p. 260; 1950, p. 8.

Remarks.—The Redbank specimens compare well with the type material. Distinguishing characteristics of this species are the somewhat overhanging shoulders of the chambers, depressed sutures, finely roughened surface with longitudinal costae, short cylindrical neck, and phialine lip of the aperture.

Length 0.30 mm. Width 0.15 mm.

Occurrence.—*Pseudouvigerina seligi* is a characteristic species of the upper Navarro of the Gulf Coast. Jennings figured it from the Mt. Laurel and the Navesink of New Jersey. Nine reports that it is abundant in the Navesink. It is common in the Redbank at Atlantic Highlands and New Egypt; and in the lower New Egypt in the Glendola, Whitesville and Clementon wells.

Types.—Figured hypotype R 5090.

PSEUDOUVIGERINA TRIANGULARIS Jennings
Pl. 4, fig. 22

Pseudouvigerina triangularis Jennings, 1936, p. 29, pl. 3, figs. 6a,b.

Remarks.—The species was originally described from the Hornerstown by Jennings. It is distinguished by the elongate test with a triangular transverse section, depressed sutures, and terminal ovate aperture.

Length 0.45 to 0.75 mm. Width 0.25 to 0.30 mm.

Occurrence.—This species occurs abundantly in the Hornerstown at the Shingle Run and Crosswicks Creek localities. It is common in the Whitesville well (200–238′) and Glendola well (301–313′).

Types.—Figured hypotype R 5091.

Genus SIPHOGENERINOIDES Cushman, 1927

SIPHOGENERINOIDES ELEGANTA (Plummer) Cushman

Pl. 4, fig. 24

Siphogenerina eleganta Plummer, 1927, p. 126, pl. 8, fig. 1.

Siphogenerinoides eleganta Cushman, 1940, p. 66, pl. 11, fig. 17; Kline, 1943, p. 46, pl. 4, fig. 18; Cooper, 1944, p. 351, pl. 54, fig. 14; Cushman, 1944, p. 42, pl. 7, fig. 8; Cushman & Todd, 1946, p. 59, pl. 10, fig. 18.

Remarks.—This species is characterized by the elongate test, the biserial early portion, alternating later chambers, coarsely punctate surface, and sharply depressed sutures.

Length 0.80 mm.

Occurrence.—The species has been recorded only from beds of Paleocene age. It occurs in the Midway of Texas, Alabama, Arkansas, Illinois, and Mississippi. It is present in the Hornerstown at the Shingle Run locality and in the Clementon well (210′).

Types.—Figured hypotype R 5092.

Family BULIMINDAE

Genus BULIMINELLA Cushman, 1911

BULIMINELLA FUSIFORMA Jennings

Pl. 4, figs. 25,26

Buliminella fusiforma Jennings, 1936, p. 30, pl. 3, fig. 18.

Buliminella cushmani Cushman (not Sandidge), 1948, p. 260, pl. XXIV, fig. 21.

Remarks.—Jennings originally described this species from the Navesink formation of New Jersey. It has been figured by Cushman as *Buliminella cushmani* from the Upper Cretaceous of Maryland. It differs from that form in possessing a larger apertural face, a somewhat elongate test that produces a slight effect of parallelism, and a last whorl which makes up the larger part of the test.

Length 0.40 mm. Width 0.13 mm.

Occurrence.—The species is very common in the Navesink and also in the Redbank at Atlantic Highlands and New Egypt. It is common in the lower New Egypt of the Glendola, Clementon, and Whitesville wells.

Types.—Figured hypotype R 5093.

Genus COLOMIA Cushman and Bermudez, 1948

COLOMIA CALIFORNICA MUNDULA Bandy

Pl. 5, figs. 1,2

Colomia californica Bandy var. *mundula* Bandy 1951, p. 512, pl. 75, figs. 12a,b.

Remarks.—This is a very distinctive subspecies. It is easily identified by the conical test with a broad, flattened apertural face; nearly flush or somewhat depressed sutures; and a characteristic broad, low, U-shaped aperture.

Length 0.25 mm. Diameter 0.25 mm.

Occurrence.—The subspecies was originally described by Bandy from the Upper Cretaceous of California. It is present only in the Redbank at Atlantic Highlands.

Types.—Figured hypotype R 5094.

Genus BUILIMINA d'Orbigny, 1826

BULIMINA ARKADELPHIANA MIDWAYENSIS Cushman and Parker

Pl. 5, fig. 9

Bulimina arkadelphiana Cuhsman & Parker var. *midwayensis* Cushman & Parker, 1936, p. 42, pl. 7, figs. 9,10; Kline, 1943, p. 47, pl. 7, fig. 9; Cushman & Parker, 1947, p. 92, pl. 21, figs. 24, 25.

Bulimina aculeata Plummer (not D'Orbigny), 1927, p. 73, pl. 4, fig. 3.

Remarks.—This small form is characterized by fine spines that cover the walls of the test, except those of the last whorl.

Length 0.40 mm. Width 0.20 mm.

Occurrence.—The subspecies occurs infrequently in the Midway of Texas and Mississippi. In the Hornerstown it is present at the Shingle Run and Crosswicks Creek localities. It is present in the Glendola well (301–302′) and the Clementon well (210′).

Types.—Figured hypotype R 5095.

BULIMINA QUADRATA Plummer

Pl. 4, fig. 27

Bulimina (*Ellipsobulimina*) *quadrata* Plummer 1927, p. 72, pl. 4, figs. 4,5.

Bulimina quadrata Jennings, 1936, p. 30, pl. 3, fig. 19.

Bulimina (*Desinobulimina*) *quadrata* Cushman, 1940, p. 67, pl. 11, fig. 21; Kline, 1943, p. 48, pl. 4, fig. 20; Cushman & Todd, 1946, p. 60, pl. 10, fig. 19; McLean, 1953, p. 9, figs. 59,60, 64.

Remarks.—Diagnostic characteristics of this species are the almost cylindrical test, and the broad, blunt, smooth, little inflated chambers.

Length 0.60 to 0.70 mm.

Occurrence.—The species has been recorded from the Midway of Alabama, Arkansas, Texas, and Mississippi. It previously has been reported from the Hornerstown and Vincentown formations. It is common in the Vincentown. In the Hornerstown it is a common form at the Shingle Run and the Crosswicks Creek localities. It is present in the Glendola well (301–302′). It occurs rarely in the Redbank at Atlantic Highlands and New Egypt. It is present in the New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5096.

Bulimina referata Jennings
Pl. 5, figs. 3,4

Bulimina referata Jennings, 1936, p. 31, pl. 3, figs. 21a,b.

Remarks.—This species is easily distinguished by its small, elongate test that is triangular in cross-section; flat, smooth chamber walls; somewhat concave apertural face; and the moderately large aperture.

Length up to 0.30 mm. Width 0.10 mm.

Occurrence.—*Bulimina referata* was origginally described from the Mt. Laurel and Navesink formations of New Jersey by Jennings. Nine reports that it is common in the Navesink. It is common in the Redbank at Atlantic Highlands, New Egypt, and in the lower New Egypt of the Clementon and Whitesville wells.

Types.—Figured hypotype R 5097.

Bulimina hornerstownensis n. sp.
Pl. 5, figs. 6,7

Test.—small, elongate, rounded in transverse section, tapering somewhat rapidly to a rounded end. Greatest width near apertural end. *Wall.*—finely perforate, smooth. *Chambers.*—increase rather rapidly in size, arranged in about 5 whorls. Somewhat inflated, especially those of last whorl. *Sutures.*—flush with surface throughout major portion of test, slightly depressed between chambers of last formed whorl. *Aperture.*—looped-shaped, with a slight lip. Length 0.25 to 0.30 mm. Width 0.12 to 0.15 mm.

Remarks.—This species is similar to *Bulimina referata* Jennings. It differs from this species mainly by the rounded transverse section and the more inflated chambers. The sutures of *B. referata* seem to be more depressed. The species differs from *B. pseudocacumenta* in the lack of any costation.

Occurrence.—The species has been observed in the Vincentown. It is present in the Hornerstown at the Shingle Run and Crosswicks Creek localities. It is present in the Glendola well (301–302′).

Types.—Holotype (USNM 626459) and

Explanation of Plate 7

Figs. *1–3*—*Pulsiphonina prima* (Plummer) *1*, Spiral view *2*, Edge view, showing aperture and pore canals *3*, Umbilical view. From the Hornerstown formation ×141.

4,5—*Kerria fallax* Rzehak *4*, Top view, showing aperture *5*, Spiral view. From the Hornerstown formation. ×43.

6–8—*Pseudoparrella glabrata* Cushman. *6*, Spiral view. *7*, Edge view, showing interiomarginal-aperture. *8*, Umbilical view. From the Redbank formation. ×185.

9,10—*Chilostomella* cf. *C. ovoidea* Reuss. *9*, Side view. *10*, Front view showing aperture. From the Redbank formation. ×61.

11–13—*Reinholdella brotzeni* n. sp. Holotype. *11*, Spiral view. *12*, Edge view. *13*, Umbilical view, showing aperture and internal partitions. From the Redbank formation. ×141.

14—*Allomorphina halli* Jennings. *14*, Umbilical view, showing umbilical aperture with thin lip. From the Hornerstown formation. ×80.

15,16—*Seabrookia stewarti* n. sp. Holotype. *15*, Side view, showing the two chambers of the last whorl. *16*, Edge view, showing aperture. From the Redbank formation. ×185.

17,18—*Pullenia americana* Cushman. *17*, Side view. *18*, Edge view, showing aperture. From the Redbank formation. ×98.

19–21—*Globigerina spiralis* Bolli. *19*, Oblique edge view. *20*, Spiral view. *21*, Umbilical view, showing umbilical aperture. From the Hornerstown formation. ×98.

22–24—*Globigerina triloculinoides* Plummer. *22*, Umbilical view, showing umbilical aperture with thin lip. *23*, Edge view. *24*, Spiral view. From the Hornerstown formation. ×98.

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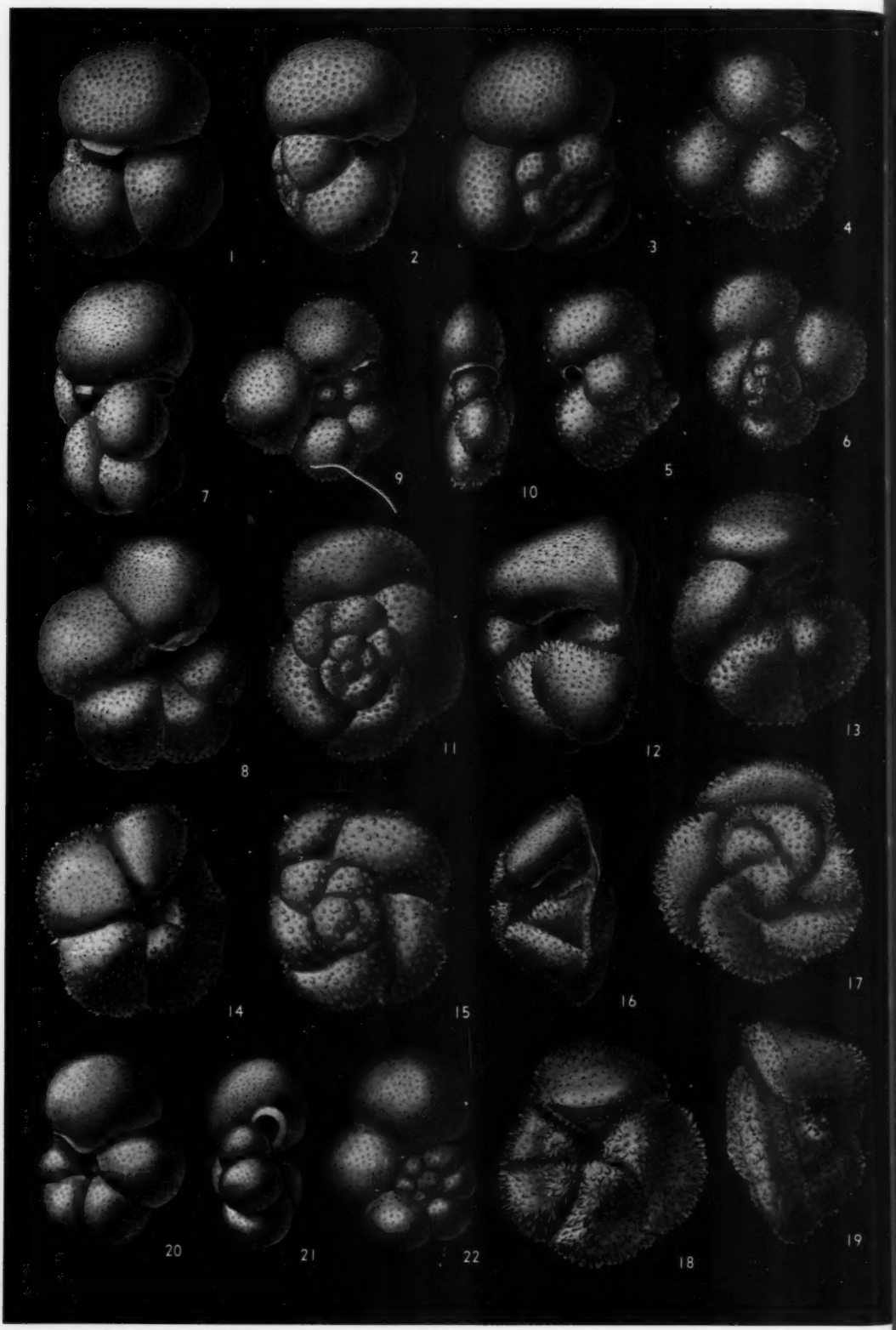
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paratypes (P 81040 and R 5028) from the Hornerstown formation, locality NJT-11.

BULIMINA PSEUDOCACUMENATA n. sp.
Pl. 5, fig. 5

Bulimina cacumenata Hofker (not Cushman & Parker), 1955, p. 9, pl. 4.

Test.—small, slightly fusiform, triangular in transverse section, with slightly concave sides, early portion tapering rather rapidly to a subacute initial end. Sides of last ¾s of test essentially parallel. *Wall.*—finely perforate, except for last whorl covered with longitudinal low costae, especially along the angular edges of the test. *Chambers.*—numerous, arranged in 5–6 whorls, those of last whorl slightly inflated. *Sutures.*—flush with surface, those of last formed whorl may be very slightly depressed. *Aperture.*—looped-shaped, with a small lip. Length 0.25 to 0.30 mm. Width 0.10 mm.

Remarks.—This species is rather similar to *Bulimina cacumenata* Cushman and Parker. However it has several distinct features. The triangular transverse section, with slightly concave parallel sides, and finely perforate walls distinguish this species from *B. cacumenata*. The costae of *B. pseudocacumenata* seem to be restricted more to the acute edges of the test than *B. cacumenata*.

Occurrence.—The species was recorded from the Vincentown formation as *B. cacumenata* by Hofker. It is present in the Hornerstown formation at Shingle Run and at Crosswicks Creek. It has been observed in the Glendola well (301–302′) and the Clementon well (210′).

Types.—Holotype (USNM 626460) and paratypes (P 81041 and R5029) from the Hornerstown formation, locality NJT-1.

Genus FISSURINA Reuss, 1850
FISSURINA OSLATUS (Shifflett)
Pl. 5, fig. 8

Entosolenia oslatus Shifflett, 1948, p.62, pl. 3, figs. 14a–c.

Remarks.—This distinctive species is easily identified by the subcircular, compressed, single chambered test with the two peripheral keels. The Hornerstown forms seem to be identical in all respects. The Redbank species possess all the diagnostic characteristics except they are about half the size of the Tertiary ones.

Length 0.10 to 0.20 mm.

Occurrence.—This species is present in the Hornerstown at the Shingle Run locality. It is rare in the Redbank at Atlantic Highlands and has been found in the Glendola well (301–302′) and in the New Egypt interval in the Clementon well.

Types.—Figured hypotype R5098.

Genus VIRGULINA d'Orbigny, 1826
VIRGULINA NAVARROANA Cushman
Pl. 5, fig. 10

Virgulina navarroana Cushman, 1933, p. 63, pl. 7, figs. 9,10; Cushman & Todd, 1943, p. 66, pl. 11, fig. 25; Cushman, 1946, p. 126, pl. 53, figs. 5–7; 1950, p. 8, pl. 4, fig. 5.

Remarks.—The Redbank forms are ident-

EXPLANATION OF PLATE 8

FIGS. *1–3—Globigerina inaequispira* Subbotina. *1*, Umbilical view, showing umbilical aperture with lip. *2*, Edge view. *3*, Spiral view. From the Hornerstown formation. ×98.

4–6—Globigerinoides daubjergensis (Bronnimann). *4*, Umbilical view, showing umbilical aperture. *5*, Edge view. *6*, Spiral view, showing supplementary aperture. From the lower Hornerstown formation of the Clementon well. ×141.

7,8—Biglobigerinella biforaminata Hofker. *7*, Edge view, showing double apertures. *8*, Side view. From the Redbank formation. ×141.

9,10—Globigerinella messinae subcarinata Bronnimann. *9*, Side view. *10*, Edge view, showing aperture. From the Redbank formation. ×141.

11–13—Globorotalia aequa Cushman and Renz. *11*, Spiral view. *12*, Edge view. *13*, Umbilical view. From the Hornerstown formation. ×141.

14–16—Globorotalia angulata (White). *14*, Umbilical view. *15*, Spiral view. *16*, Edge view. From the Hornerstown formation. ×98.

17–19—Globorotalia apanthesma Loeblich and Tappan. *17*, Spiral view. *18*, Umbilical view. *19*, Edge view. From the Hornerstown formation. ×98.

20–22—Globorotalia compressa (Plummer). *20*, Umbilical view. *21*, Edge view. *22*, Spiral view. From the lower Hornerstown formation of the Clementon well. ×185.

ical with the type material. The elongate, broadly rounded, tapering test, with a short spine at the initial end, somewhat inflated chambers, distinct slightly depressed sutures, and comma shaped aperture are distinctive characteristics of this species.

Length 0.35 mm. Width 0.10 mm.

Occurrence.—*Virgulina navarroana* is restricted to the uppermost Navarro of Texas and Arkansas. The rare occurrence of the form has been reported by Nine in the Navesink of New Jersey. It is present in the Redbank at Atlantic Highlands and at New Egypt. It is present also in the lower New Egypt of the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5099.

Genus LOXOSTOMA Ehrenberg, 1854

LOXOSTOMA PLAITUM LIMBOSUM Cushman

Pl. 5, fig. 11

Loxostroma plaitum (Carsey) Cushman var. *limbosum* Cushman, 1931, p. 52, pl. 8, fig. 10; 1946, p. 131, pl. 54, fig. 15.

Loxostomum plaitum (Carsey) var. *limbosum* Cushman & Todd, 1943, p. 67, pl. 11, fig. 27; Cushman, 1948, p. 262, pl. XXV, fig. 7.

Loxostomum plaitum Cushman (not Carsey), 1931, p. 310, pl. 33, figs. 16a,b.

Remarks.—This form is identified by its slender, elongate, slightly tapering test, that is somewhat twisted and by its limbate sutures, that are raised in the early portion.

Length up to 0.80 mm. Width 0.20 mm.

Occurrence.—It is restricted to the Navarro of the Gulf Coast and has been figured by Cushman from the Upper Cretaceous of Maryland. It is common in the Redbank at Atlantic Highlands, New Egypt and in the lower New Egypt of the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R5100.

Genus ANGULOGERINA Cushman, 1927

ANGULOGERINA WILCOXENSIS (Cushman and Ponton) Cushman and Garrett

Pl. 5, fig. 12

Pseudovigerina wilcoxensis Cushman & Ponton, 1932, p. 66, pl. 8, fig. 18.

Angulogerina wilcoxensis Cushman & Garrett, 1939, p. 84, pl. 14, figs. 24,25; Toulmin, 1941, p. 599, pl. 80, fig. 30; Cushman, 1944, p. 44, pl. 7, fig. 18; Shifflett, 1948, p. 64, pl. 3, fig. 18.

Remarks.—The Hornerstown forms compare well with the type material. Distinguishing characteristics are the triangular transverse section of the test, two parallel distinct ribs along the angles, the coarsely perforate wall, and a terminal aperture with a short neck and lip.

Length 0.35 mm. Width 0.15 mm.

Occurrence.—The species has been recorded from the Wilcox and Naheola of Alabama. It has been reported from the Salt Mountain limestone of Alabama and the Aquia formation of Maryland and Virginia. It also occurs in the Vincentown formation. In the Hornerstown it is present at the Shingle Run and Crosswicks Creek localities. It has been found in the Glendola well (301–302′) and the Clementon well (210′).

Types.—Figured hypotype R 5101.

Family ELLIPSOIDINIDAE

Genus NODOSARELLA Rzehak, 1895

NODOSARELLA IRREGULARIS n. sp.

Pl. 5, figs. 13,14

Test.—elongate, slightly curved, irregular, greatest width at last chamber. *Wall.*—calcareous, smooth. *Chambers.*—arrangement obscure in early portion, alternating to rectilinear in later stages. Rounded in section, later ones slightly cylindrical in shape and inflated. Increase rapidly in size as added, last one frequently forming ⅓ length of test. *Sutures.*—straight in the rectilinear series, oblique where chambers alternate. *Aperture.*—terminal, a narrow elongate slit with a lip at one side. Length 0.70 mm. to 1.30 mm. Diameter 0.22 to 0.30 mm.

Remarks.—The species is similar to *Nodosarella attenuata* (Plummer). *N. attenuata* is a more slender species. It tapers more gradually and is not quite so irregular as this species. *N. irregularis* n. sp. differs from *N. paleocenica* Cushman and Todd by the irregular test and lack of a narrow initial end.

Occurrence.—The species is present in the Hornerstown at the Shingle Run and Crosswicks Creek localities.

Types.—Holotype (USNM (626461) and paratypes (P 81042 and R 5030) from the Hornerstown formation, locality NJT-1.

NODOSARELLA MONMOUTHENSIS n. sp.

Pl. 5, figs. 15,16

Test.—elongate, slender, curved, somewhat tapering, circular in transverse section,

greatest width near apertural end. *Wall.*—calcareous, smooth, finely perforate. *Chambers.*—slightly inflated, especially in later stages of test, longer than broad. *Sutures.*—flush with surface in initial portion, slightly depressed in later portion. *Aperture.*—subterminal, semielliptical, with an arched hoodlike portion over the opening.

Length up to 1.7 mm. Diameter 0.20 mm.

Remarks.—This species resembles *Nodosarella texana* Cushman. It differs from that species in that the test is not so long; tapers more; and the sutures are more depressed.

Occurrence.—This is a common species in the Redbank at Atlantic Highlands. It is present in the Redbank at New Egypt and in the lower New Egypt of the Clementon, Glendola, and Whitesville wells.

Types.—Holotype (USNM 626462) and paratypes (P 81043 and R 5031) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Genus ELLIPSONODOSARIA A. Silvestri, 1900

ELLIPSONODOSARIA PLUMMERAE Cushman

Pl. 5, fig. 20

Nodosaria sagrinensis Plummer (not Bagg), 1927, p. 85, pl. 4, fig. 16.
Nodogenerina sagrinensis Jennings (not Bagg), 1936, p. 29, pl. 3, fig. 17.
Ellipsonodosaria plummerae Cushman, 1940, p. 69, pl. 12, figs. 4,5; Kline, 1943, p. 51, pl. 5, fig. 8; Cooper, 1944, p. 352, pl. 54, figs. 18,19; Cushman & Todd, 1946, p. 61, pl. 10, fig. 24.
Ellipsonodosaria sagrinensis Cooper (not Bagg), 1944, p. 352, pl. 54, fig. 22.

Remarks.—This distinctive species is identified by the elongate, very slightly tapering test, the longitudinal costae that are broken into spines, and the aperture with a neck and slight lip.

Length 0.60 to 1.0 mm. Diameter 0.10 to 0.20 mm.

Occurrence.—The species is known from the Midway of Texas, Alabama, Arkansas, Mississippi, and Illinois. Jennings has figured it previously from the Hornerstown as *Nodogenerina sagrinensis.* It is common in the Hornerstown at the Shingle Run and Crosswicks Creek localities. It is present in the Glendola well (301–302′) and Clementon well (210′).

Types.—Figured hypotype R 5102.

ELLIPSONODOSARIA STEPHENSONI SPECIOSA Cushman

Ellipsonodosaria stephensoni Cushman var. speciosa Cushman, 1938, p. 47, pl. 8, fig. 3.

Remarks.—Fragmentary specimens of this form are present in the Redbank at Atlantic Highlands. Complete specimens were found in the well material. They compare well with the type material, but generally have finer spines

Length up to 1.0 mm. Diameter 0.10 mm.

Occurrence.—It has been recorded only from the Arkadelphia of Arkansas. It is rare in the Redbank at Atlantic Highlands. It is more common in the lower New Egypt of the Clementon, Glendola and Whitesville wells.

Family VALVULINERIINAE

Genus VALVULINERIA Cushman, 1926

VALVULINERIA ALLOMORPHINOIDES (Reuss) Cushman

Pl. 6, fig. 1

Valvulina allomorphinoides Reuss, 1860, p. 223, pl. 11, figs. 6a–c.
Valvulineria allomorphinoides Cushman, 1931, p. 43, pl. 6, figs. 2a–c; 1931, p. 53, pl. 9, figs. 6a–c; Brotzen, 1936, p. 153, pl. 11, figs. 1a–c, text fig. 56; Cushman, 1940, p. 70, pl. 12, fig. 9; Cushman & Hedberg, 1941, p. 96, pl. 23, figs. 9a–c; Kline, 1943, p. 52, pl. 5, figs. 11,12; Cushman, 1946, p. 138, pl. 57, figs. 6,7; 1948, p. 263, pl. XXV, fig. 12; 1951, p. 50, pl. 14, figs. 8,9.

Remarks.—This species has a wide distribution in the Gulf Coast. It occurs in beds from Austin to Midway. The species is distinguished by the low trochospiral test, broadly rounded axial periphery, slightly inflated chambers, and aperture that is covered by an overhanging lip.

Diameter to 0.40 mm.

Occurrence.—The species occurs rarely in the Navesink and in the Redbank at Atlantic Highlands and New Egypt. It is present in the lower New Egypt of the Whitesville, Clementon, and Glendola wells. It also occurs in the Hornerstown at Shingle Run.

Types.—Figured hypotype R 5103.

Genus GAVELINELLA Brotzen, 1942

GAVELINELLA LIMBATA n. sp.

Pl. 5, figs. 17–19

Gavelinella midwayensis Hofker (not Plummer), 1955, p. 14, pl. 3.

Test.—nearly planispiral, biconvex, com-

pressed, inner whorls on spiral side depressed. Equatorial periphery smooth to lobate. Axial periphery rounded to subacute. *Wall.*—somewhat coarsely perforated. *Chambers.*—9–11 in the last whorl, narrow increasing gradually in size. Non-inflated, last one slightly inflated toward umbilical side. *Sutures.*—strongly limbate, raised. Spiral side: rather strongly curved. Umbilical side: radial to gently curved, coalescing to form an area of smooth shell material around umbilicus. *Umbilicus.*—deep, narrow. *Aperture.*— interiomarginal, umbilical—extraumbilical with a thin peripheral lip and an umbilical lip. The last 4 or 5 umbilical lips extend into the umbilicus, the previous ones are obscured by growth of shell material. Diameter up to 0.55 mm. Thickness up to 0.25 mm.

Remarks.—This species is similar to *Anomalina pseudoammonoides* McLean. It differs from this species in the non-inflated chambers and the limbate sutures.

Occurrence.—The species is present in the Vincentown formation. It occurs commonly in the Hornerstown at Shingle Run and Crosswicks Creek. It is present in the Glendola well (301′–302′) and Clementon well (210′).

Types.—Holotype (USNM 626463) and paratypes (P 81044 and R 5032) from the Hornerstown formation, locality NJT-1.

Genus EPONIDES Montfort, 1808
EPONIDES LUNATA Brotzen

Eponides lunata Brotzen, 1948, p. 77, pl. 10, figs. 17,18.

Remarks.—The Hornerstown forms compare well with material from the Paleocene of Sweden. The species is characterized by a biconvex test, sharply acute axial periphery, and a somewhat lobate equatorial periphery.

Diameter 0.20 mm.

Occurrence.—The species is rare in the Hornerstown at the Crosswicks Creek locality.

EPONIDES PLUMMERAE Cushman
Pl. 5, figs. 21–23

Eponides plummerae Cushman, 1948, p. 44, pl. 8, fig. 9.
Truncatulina tenera Plummer (not H. B. Brady), 1927, p. 146, pl. 9, fig. 5.
Eponides cf. *E. tenera* Kline, 1943, p. 53, pl. 5, figs. 16–18.
Eponides cf. *E. haidingerii* Cushman & Todd (not d'Orbigny), 1946, p. 62, pl. 11, figs. 5,6.
Eponides sp. Cushman, 1940, p. 71, pl. 12, fig. 8.

Remarks.—The Hornerstown forms compare well with the type material except for size. They are slightly larger than the types. The diagnostic features are the biconvex test, number of chambers, and the sutural arrangement.

Diameter 0.50 mm. Thickness 0.40 mm.

Occurrence.—The species has been recorded from the upper Midway of Texas, Mississippi, and Alabama and the Paleocene of Arkansas. It occurs rarely in the Hornerstown at the Crosswicks Creek locality.

Types.—Figured hypotype R 5104.

Genus GYROIDINOIDES Brotzen, 1942
GYROIDINOIDES SUBANGULATA
(Plummer)
Pl.5, figs. 24, 25

Rotalia soldanii D'Orbigny var. subangulata Plummer, 1927, p. 154, pl. 12, fig. 1.
Gyroidina subangulata Cushman, 1940, p. 71, pl. 12, fig. 7; Cushman & Renz, 1942, p. 11, pl. 2, fig. 18; Kline, 1943, p. 53, pl. 5, figs. 13–15; Cushman & Todd, 1946, p. 62, pl. 11, figs. 2–4; Cushman, 1951, p. 51, pl. 14, figs. 14,15.

Remarks.—The species is distinguished by the nearly plano-convex test, strongly convex umbilical side, number of chambers, and the slightly depressed sutures around the umbilicus. The Hornerstown forms are somewhat larger than measurements given by Plummer.

Diameter 0.40 to 0.55 mm.

Occurrence.—This species has been recorded from beds of Midwayan age in the Gulf Coast. It is present in the Vincentown. The species occurs commonly in the Hornerstown at Shingle Run and at Crosswicks Creek.

Type.—Fgured hypotype R 5105.

GYROIDINOIDES IMITATA n sp.
Pl. 6, figs. 2–4

Test.—moderately high trochospiral, spiral side generally flat, umbilical side convex; nearly circular in outline, somewhat lobulate. Axial periphery subacute. *Wall.*—calcareous, smooth, finely perforate. *Chambers.*—spiral side: about 20–23 arranged in 2½ whorls, 8,9 in last whorl, rhomboid in

shape, gradually increasing in size, last few very slightly inflated. Umbilical side: wedge-shaped, later ones somewhat inflated. *Sutures.*—spiral side: slightly oblique, limbate, flush with surface in initial stages, to some extent depressed in later portions. Umbilical side: radiate, gently curving at the periphery, limbate, flush with surface becoming somewhat depressed between last few chambers. Spiral suture depressed. *Umbilicus.*—deep, narrow. *Aperture.*—at the base of the last formed chamber, a thin slit extending from the periphery into the umbilicus, with a flattened narrow lip, that broadens and projects over the umbilicus. Diameter up to 0.30 mm.

Remarks.—This species is similar to *Valvulineria* cf. *V. umbilicatula* (D'Orbigny) Cushman. It differs from that form in possessing more chambers, limbate sutures, less inflated chambers, and a more delicate lobe covering the umbilicus.

Occurrence.—The species is common in the Redbank at Atlantic Highlands and New Egypt. It is present in the Navesink. It also is present in the lower New Egypt of the Whitesville, Clementon, and Glendola wells.

Types.—Holotype (USNM 626464) and paratypes (P 81045 and R 5033) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Family EPISTOMINIDAE
Genus LAMARCKINA Berthelin, 1881
LAMARCKINA RUGULOSA Plummer
Pl. 6, figs. 5,6

Lamarckina rugulosa Plummer, 1926, p. 8, pl. 3, figs. 6a–c; 1927, p. 140, pl. 9, figs. 3a–c; Cushman, 1951, p. 49, pl. 13, fig. 24.

Remarks.—This very distinctive species is easily identified by the moderately compressed to almost globular test, broadly rounded axial periphery, very smooth polished umbilical side, highly granular spiral side, with the spiral suture commonly marked by smooth shell material.

Largest diameter 0.55 mm.

Occurrence.—Heretofore this species has been known only from the Midway of Texas and Mississippi. Plummer had considered it a diagnostic fossil for this part of the geologic section. It is very common in the Redbank at Atlantic Highlands.

Types.—Figured hypotype R 5106.

LAMARCKINA PRAENAHEOLENSIS n. sp.
Pl. 6, figs. 18–20

Test.—very low trochospiral, compressed, about equally biconvex, higher than wide. Equatorial periphery slightly lobulate. Axial periphery acute. *Wall.*—calcareous, smooth, polished, finely perforate. *Chambers.*—spiral side: about 9 arranged in 1½ whorls, 6 in adult-whorl increasing rather rapidly in size, imperfectly crescent shaped. Umbilical side: bluntly wedge-shaped, slightly inflated. *Sutures.*—spiral side: strongly oblique, somewhat, curved, limbate, flush with surface. Umbilical side: radiate, depressed, especially near umbilical area. *Umbilicus.*—open, shallow. *Aperture.*—a rather high arch, interiomarginal—umbilical, covered by a thin plate extending from the peripheral side to the umbilicus. Diameter up to 0.40 mm.

Remarks.—This species is similar to *Lamarckina naheolensis* Cushman and Todd. It differs from this species in the shallow umbilicus, smaller number of chambers in the adult whorl, and the depressed sutures on the umbilical side. *L. praenaheolensis* n. sp. may represent a possible ancestor to *L. naheolensis.*

Occurrence.—The species is present in the Redbank at Atlantic Highlands but it is not common.

Types.—Holotype (USNM 626465) and paratypes (P 81046 and R 5034) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Genus HÖGLUNDINA Brotzen, 1948
HÖGLUNDINA SUPRACRETACEA
(ten Dam) Bandy
Pl. 6, figs. 10–12

Epistomina supracretacea ten Dam, 1948, p. 163, pl. 1, fig. 8.
Höglundina supracretacea Bandy, 1951, p. 507, pl. 74, figs. 3a–c.
Epistomina caracolla Franke (not Roemer), 1925, p. 88, pl. 8, fig. 10; Cushman (not Roemer), 1931, p. 55, pl. 10, fig. 1; Cushman & Todd (not Roemer), 1943, p. 69, pl. 12, fig. 5; Cushman, 1946, p. 142, pl. 59, fig. 2 (not fig. 1).

Remarks.—This species is identified by the low trochospiral, biconvex test, more convex on the umbilical side, slightly lobulate equatorial periphery, acute axial periph-

ery with a slight keel; 5–8, average 6, chambers of the last whorl that gradually increase in size; strongly limbate, slightly curved oblique sutures of the spiral side; straight, radial, somewhat limbate sutures of the umbilical side that fuse with the central umbo; and the interiomarginal-umbilical and lateromarginal apertures.

Diameter up to 0.70 mm.

Occurrence.—The species is known from the Taylor and Navarro of the Gulf Coast and the Upper Cretaceous of California. It is common in the Redbank at Atlantic Highlands. It is present in the lower New Egypt of the Glendola and Whitesville wells.

Types.—Figured hypotype R 5107.

Genus PARRELLA Finlay, 1939
PARRELLA EXPANSA Toulmin

Parrella expansa Toulmin, 1941, p. 604, text figs. 3, 4f, 4c; Kline, 1943, p. 54, pl. 5, figs. 19,20.

Truncatulina culter Plummer (not Parker & Jones), 1927, p. 147, pl. 10, fig. 1, pl. 15, fig. 2.

Pulvinulinella culter (Parker & Jones) var. *mexicana* Cushman (not Cole), 1940, p. 72, pl. 12, fig. 12.

Pulvinulinella culter (Parker & Jones) var. *midwayana* Cushman & Todd, 1946, p. 63, pl. 11, fig. 12.

Remarks.—The New Egypt specimens are identical with holotype and paratype material. It is identified by the umbilico-convex test, thin peripheral flange, and the characteristic apertures.

Diameter 0.40 mm.

Occurrence.—The species was described from the Wills Point of Texas by Toulmin. It is known only from beds of Midwayan age. It is present in the New Egypt in the Clementon, Whitesville, and Glendola wells; and in the lower Hornerstown in the Clementon well.

PARRELLA CONVEXA n. sp.
Pl. 6, figs. 13–15

Test.—trochospiral, biconvex. Equatorial periphery subcircular. Axial periphery sharply acute with a distinct keel. *Wall.*—smooth, perforate. *Chambers.*—umbilical side: 8–9 in final whorl, increasing uniformly in size. Final one sometimes slightly inflated; spiral side: obscure in earlier whorls because of shell growth. Keel of next to last whorl forms a partial spiral suture. *Sutures.*—umbilical side: straight radiating from a small umbilical filling. Flush with surface, except between last few chambers, slightly depressed. Spiral side: limbate, oblique, curving toward the periphery, may be slightly raised. *Aperture.*—composed of two portions: an areal one consisting of a narrow slit, surrounded by a thin lip, and extending from the periphery into the apertural face at an acute angle, then curving upward and back toward the periphery. A short, narrow interiomarginal one with a thin lip situated at the base of the apertural face near the umbilical side. Diameter up to 0.70 mm. Thickness up to 0.30 mm.

Remarks.—This species resembles *Parrella expansa* Toulmin from the Wills Point formation of Texas. It differs from this species by the biconvex test, straight radial sutures of the umbilical side, and the characteristic curved areal aperture.

Occurrence.—This species is present in the Hornerstown at Shingle Run and at Crosswicks Creek. It also is present in the Glendola well (301–302′).

Types.—Holotype (USNM 626466) and paratypes (P 81047 and R 5035) from the Hornerstown formation, locality NJT-11.

Genus CERATOBULIMINA Toula, 1915
CERATOBULIMINA CRETACEA Cushman and Harris
Pl. 6, figs. 16,17

Ceratobulimina cretacea Cushman & Harris, 1927, p. 173, pl. 29, figs. 1a–c; pl. 30, fig. 11; Cushman, 1931, p. 56, pl. 10, figs. 2a–c; Cushman & Todd, 1943, p. 70, pl. 12, fig. 7; Cushman, 1946, p. 143, pl. 59, figs. 5,7; Bandy, 1951, p. 507, pl. 73, figs. 20a–c.

Remarks.—The Redbank forms compare well with the type material. Diagnostic features of this species are the oval, biconvex test; slightly lobulate equatorial periphery; rounded axial periphery; chambers that increase rapidly in size; slightly limbate sutures, and the aperture that extends somewhat into the apertural face and is covered by a thin lip.

Largest diameter 0.60 mm.

Occurrence.—This species is confined to beds of Navarroan age in the Gulf Coast. Bandy has recorded it from the Upper Cretaceous of California. In New Jersey it is common in the Redbank at Atlantic Highlands. It is present in the lower New Egypt

of the Glendola and Whitesville wells.

Types.—Figured hypotype R 5108.

CERATOBULIMINA PERPLEXA (Plummer) Cushman and Harris

Rotalia perplexa Plummer, 1927, p. 156, pl. 12, fig. 2.

Ceratobulimina perplexa Cushman & Harris, 1927, p. 173, pl. 29, fig. 2; Cushman & Todd, 1942, p. 41, pl. 7, figs. 23,24; Cushman, 1946, p. 108, pl. 17, figs. 3–5; Brotzen, 1948, p. 123, pl. 19, fig. 1.

Remarks.—Distinguishing features of this species are the oval, compressed test, curved, limbate, tapering sutures of the spiral side, and the radial depressed sutures of the umbilical side.

Length 0.40 mm.

Occurrence.—A single specimen was found in the Hornerstown at Shingle Run and in the NJT-24 Hornerstown locality.

Genus PULSIPHONINA Brotzen, 1948

PULSIPHONINA PRIMA (Plummer)

Pl. 7, figs. 1–3

Siphonina prima Plummer, 1927, p. 148, pl. 12, figs. 4a–c; Jennings, 1936, p. 33, pl. 4, fig. 3; Cushman & Todd, 1943, p. 69, pl. 12, fig. 6; Cushman, 1946, p. 143, pl. 59, figs. 3–5; 1950, p. 9, pl. 4, fig. 17.

Remarks.—This is a very distinctive species. It is easily identified by the very low trochospiral, considerably compressed, biconvex test; somewhat lobulate equatorial periphery; sharply acute axial periphery; the pore canals that produce the serrate periphery; the crescent-shaped chambers of the spiral side; the smooth punctate walls; obliquely curved sutures of the spiral side; radial, slightly depressed sutures of the umbilical side; and the small, narrow apertural opening that is situated below the peripheral margin on the anterior part of the last chamber. This form was originally described by Plummer from the Midway of Texas. Plummer recognized that this species lacked the tubular extension of the aperture, that is characteristic of true *Siphonina*. Brotzen (1948) proposed a new subgenus *Pulsiphonina*, for such species where the apertural neck is lacking or very indistinct, with *Siphonina prima* Plummer as the genotype.

Diameter 0.30 mm. Thickness 0.10 mm.

Occurrence.—This species is found in beds of late Navarroan age and Midwayan age in the Gulf Coast. It occurs in the Navesink formation of New Jersey. It is present in the Redbank at Atlantic Highlands and New Egypt. In the Hornerstown it is present at the Shingle Run and Crosswicks Creek localites, and is found in the Glendola well (301–302′), and the Clementon well (210′).

Types.—Figured hypotype R 5109.

Genus ALABAMINA Toulmin, 1941

ALABAMINA MIDWAYENSIS Brotzen

Pl. 6, figs. 21–22

Alabamina midwayensis Brotzen, 1948, p. 99, pl. 16, figs. 1,2, text-figs. 25,26.

Pulvinulina exiqua Plummer, 1926, p. 150, pl. 11, figs. 3a–c.

Pulvinulina exiqua var. *obtusa* Plummer, 1926, p. 151, pl. 11, figs. 2a–c.

Pulvinulina grata Franke, 1927, pl. 4, fig. 2.

Pulvinulinella exiqua var. *obtusa* Jennings, 1936, p. 34, pl. 4, figs. 4a,b.

Pulvinulinella obtusa Cushman & Renz, 1942, p. 11, pl. 11, fig. 4.

Remarks.—A majority of the Hornerstown forms are biconvex and have an acute axial periphery. These seem to grade into forms with an obtuse axial periphery and a flattened spiral side. Such forms are close to *Alabamina wilcoxensis* Toulmin. The forms with an acute axial periphery are identical with Plummer's figures of *Pulvinulina exiqua* from the Midway of Texas.

Diameter up to 0.50 mm.

Occurrence.—This species is found in the Midway of Texas, and the Paleocene of Sweden and Denmark. Similar forms occur in the Vincentown. In the Hornerstown it is common at the Shingle Run and Crosswicks Creek localities.

Types.—Figured hypotype R 5110.

Genus KARRERIA Rzehak, 1891

KARRERIA FALLAX Rzehak

Pl. 7, figs. 4–5

Karreria fallax Rzehak, 1891, p. 40, pl. 7, figs. 7,8; Franke, 1927, p. 40, pl. 4, fig. 7; Brotzen, 1948, p. 115, pl. 18, fig. 3, text figs. 34–37.

Remarks.—The Hornerstown forms are typical of this species. They have from 1 to 3 chambers in the rectilinear series. They agree with the forms that occur in the Swedish Paleocene.

Length 1.10 mm. Width 0.60 mm.

Occurrence.—The species was described from the Tertiary of Austria by Rzehak. It has been recorded from the Paleocene of Denmark and Sweden. It also occurs in the Danian of Sweden. In the Hornerstown this species is present only at the Crosswicks Creek locality.

Types.—Figured hypotype R 5111.

Genus PSEUDOPARRELLA Cushman and ten Dam, 1948

PSEUDOPARRELLA GLABRATA Cushman

Pl. 7, figs. 6–8

Pseudoparrella glabrata Cushman, 1938, p. 66, pl. 11, fig. 4; Cushman & Todd, 1943, p. 70, pl. 12, fig. 8, Cushman & Deaderick, 1944, p. 339, pl. 53, figs. 23,24.

Remarks.—The Redbank forms are smaller than the types, but agree in all other aspects. The low trochoid, compressed, biconvex test, with subacute axial periphery; the 15 chambers arranged in 2½ whorls, with 6 in the last whorl, gradually increasing in size; the somewhat limbate sutures, strongly oblique, slightly curved on the spiral side; radial sutures that curve gently toward the periphery on the umbilical side; and the elongate apertural slit situated below the peripheral margin on the anterior part of the last chamber are typical features of this species.

Diameter 0.20 mm.

Occurrence.—In the Gulf Coast this species is most characteristic in beds of Navarroan age. It occurs rarely in beds of Tayloran age. In the Redbank at Atlantic Highlands and New Egypt this species is fairly common. It is present in the lower New Egypt of the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5112.

PSEUDOPARRELLA MINUTA n. sp.

Pl. 6, figs. 7–9

Test.—minute, biconvex, low trochospiral, compressed. Equatorial periphery circular. Axial periphery subacute. *Wall.*—smooth, finely perforate. *Chambers.*—7 in final whorl, gradually increasing in size, not inflated. *Sutures.*—Nonlimbate, flush with surface. Last suture on umbilical side may be somewhat compressed. Spiral side: oblique, gently curved. Umbilical side: radial to very slightly curved. *Aperture.*—interiomarginal-areal, a narrow somewhat comma-shaped opening, parallel to the plane of coiling. Diameter up to 0.15 mm.

Remarks.—This species differs from *Pseudoparrella glabrata* (Cushman) by the smaller size and non-limbate sutures.

Occurrence.—The species is present in the Vincentown formation. It occurs commonly in the Hornerstown at Shingle Run and at Crosswicks Creek. It is present in the Glendola well (301–302′).

Types.—Holotype (USNM 626467) and paratypes (P 81048 and R 5036) from the Hornerstown formation, locality NJT-1.

Family AMPHISTEGINIDAE

Genus REINHOLDELLA Brotzen, 1948

REINHOLDELLA BROTZENI n. sp.

Pl. 7, figs. 11–13

Test.—high trochospiral, spiral side moder-

EXPLANATION OF PLATE 9

FIGS. *1–3—Globorotalia perclara* Loeblich and Tappan. *1*, Spiral view. *2*, Umbilical view. *3*, Edge view. From the Hornerstown formation. ×141.

4–6—Globorotalia elongata Glaessner. *4*, Spiral view. *5*, Umbilical view. *6*, Edge view. From the Hornerstown formation. ×141.

7–9—Globorotalia imitata Subbotina. *7*, Edge view. *8*, Spiral view. *9*, Umbilical view. From the Hornerstown formation. ×185.

10–12—Globorotalia pseudomenardii Bolli. *10*, Edge view. *11*, Spiral view. *12*, Umbilical view. From the Hornerstown formation. ×185.

13–15—Globorotalia convexa Subbotina. *13*, Edge view. *14*, Umbilical view. *15*, Spiral view. From the Hornerstown formation. ×141.

16–18—Globorotalia redbankensis n. sp. Holotype. *16*, Spiral view. *17*, Edge view, showing compressed biconvex test and extraumbilical-umbilical aperture. *18*, Umbilical view, showing the deep, narrow umbilicus and the rather wide umbilical lip. From the Redbank formation. ×185.

19–21—Globorotalia pseudobulloides (Plummer). *19*, Spiral view. *20*, Edge view. *21*, Umbilical view. From the lower Hornerstown formation of the Clementon well. ×141.

22–24—Globorotalia monmouthensis n. sp. Holotype. *22*, Edge view, showing the extraumbilical-umbilical aperture and the compressed biconvex test. *23*, Umbilical view, showing the small narrow umbilicus. *24*, Spiral view. From the Redbank formation. ×185.

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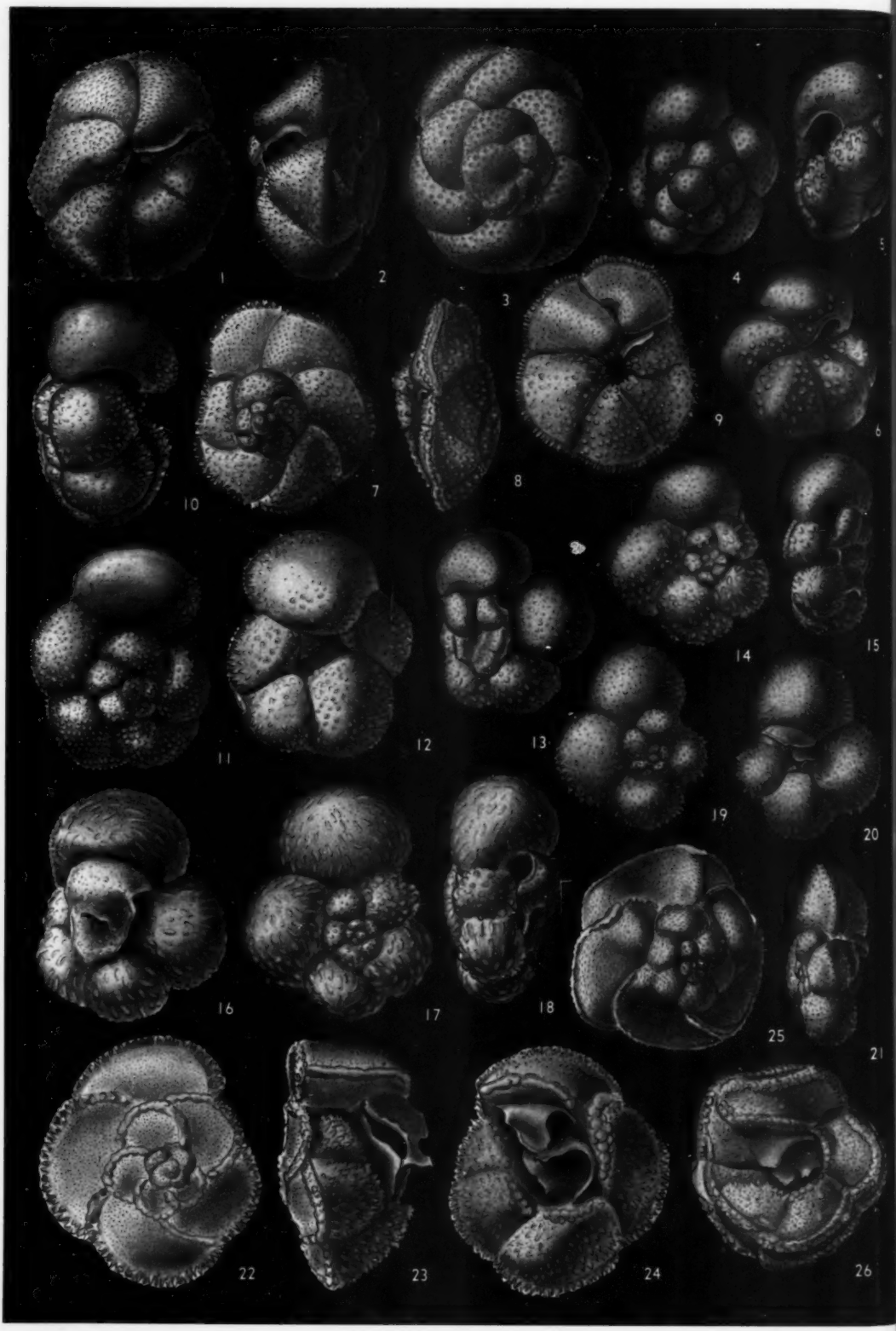
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ately to strongly convex, umbilical side flat to slightly concave; conical in shape, nearly circular in outline. Axial periphery acute. *Wall.*—aragonitic, smooth, finely perforate. *Chambers.*—spiral side: about 10–12 arranged in 2½ whorls, 4 in last whorl, elongate crescent shaped, increasing gradually in size. Umbilical side: wedge-shaped; internal partitions loop-shaped reaching approximately half the distance from center to periphery. *Sutures.*—spiral side: strongly oblique, somewhat curved, flush with surface. Umbilical side: radiate, slightly depressed. *Aperture.*—small, low arch; interiomarginal-umbilical. Diameter up to 0.30 mm.

Remarks.—Heretofore this genus has been known only from strata of Jurassic age. Because of the aragonitic composition of the test, it is not easily preserved. Therefore it would be found only in well preserved faunas such as that present in the Redbank.

Occurrence.—This species is present in the Redbank at Atlantic Highlands. It occurs rarely in the lower New Egypt of the Glendola and Whitesville wells.

Types.—Holotype (USNM 626468) and paratypes (P 81049 and R 5037) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Family CHILOSTOMELLIDAE

Genus ALLOMORPHINA Reuss, 1850

ALLOMORPHINA HALLI Jennings

Pl. 7, fig. 14

Allomorphina halli Jennings, 1936, p. 34, pl. 4, fig. 5; Brotzen, 1948, p. 127, pl. 19, figs. 4a–c, text figs. 39–41.

Allomorphina trigona (non Reuss) Franke, 1927, p. 12, pl. 1, fig. 11.

Remarks.—This species was described from the Hornerstown by Jennings. It is identified by the bluntly triangular outline of the test, the depressed sutures, and the characteristic aperture. A comparison with the Swedish Paleocene material shows the New Jersey specimens are identical.

Diameter up to 0.40 mm.

Occurrence.—The species occurs in the Paleocene of Sweden and Denmark. It is very common in the Hornerstown at Shingle Run and at Crosswicks Creek.

Types.—Figured hypotype R 5113.

Genus CHILOSTOMELLA Reuss, 1850

CHILOSTOMELLA cf. C. OVOIDEA Reuss

Pl. 7, figs. 9,10

Chilostomella cf. *C. ovoidea* (Reuss) Cushman & Hedberg, 1941, p. 98, pl. 23, fig. 16; Cushman, 1946, p. 146, pl. 66, fig. 14.

Remarks.—The Redbank forms seem to

EXPLANATION OF PLATE 10

FIGS. *1–3—Globorotalia trichotrocha* Loeblich and Tappan. *1*, Umbilical view, showing umbilicus. *2*, Edge view, showing subangular axial periphery. *3*, Spiral view. From the Hornerstown formation. ×141.

4–6—Globorotalia reissi Loeblich and Tappan. *4*, Spiral view. *5*, Edge view, showing rounded axial periphery and nearly smooth walls. *6*, Umbilical view. From the Hornerstown formation. ×185.

7–9—Globorotalia crosswicksensis n. sp. Holotype. *7*, Spiral view, showing keel ornamented with coarse spines. *8*, Edge view, showing compressed biconvex test and sharply acute axial periphery. *9*, Umbilical view, showing the narrow deep umbilicus and the apertural lip. From the Hornerstown formation. ×98.

10–12—Globorotalia strabocella Loeblich and Tappan. *10*, Edge view, showing flattened spiral side. *11*, Spiral view. *12*, Umbilical view, showing open umbilicus. Specimen shows development of a nearly smooth walled ultimate chamber. From the Hornerstown formation. ×98.

13–15—Rugoglobigerina reicheli pustulata Bronnimann. *13*, Umbilical view, showing tegilla and infralaminal and intralaminal accessory apertures. *14*, Spiral view. *15*, Edge view. From the Redbank formation. ×98.

16–18—Rugoglobigerina rugosa rugosa (Plummer). *16*, Umbilical view, showing tegilla and infralaminal and intralaminal accessory apertures. *17*, Spiral view. *18*, Edge view. From the Redbank formation. ×98.

19–21—Rugoglobigerina jerseyensis n. sp. Holotype. *19*, Spiral view. *20*, Umbilical view, showing spinose walls and development of a tegilla and infralaminal accessory apertures. *21*, Edge view, showing compressed test. From the Redbank formation. ×98.

22–24—Globotruncana monmouthensis n. sp. Holotype. *22*, Spiral view, showing smooth walls. *23*, Edge view, showing the umbilico-convex test. *24*, Umbilical view, showing spinose surface and tegilla and infralaminal and intralaminal accessory apertures. From the Redbank formation. ×80.

25,26—Globotruncana contusa (Cushman). *25*, Spiral view. *26*, Umbilical view, showing tegilla and infralaminal and intralaminal accessory apertures. From the Redbank formation. ×61.

be the same as the species figured by Cushman from the Upper Cretaceous Colon shale of Colombia. Characteristics of this species are the somewhat elongate subcylindrical test, sides nearly parallel, except at either end which is rounded and tapers very slightly; fine perforations with widely scattered coarse perforations; and the long narrow aperture that extends the width of the test, and is covered by a thin lip. *Chilostomella ovoidea* Reuss was described from the Miocene of Austria. It differs from the Redbank species in being more elongate, wider, lacking the nearly parallel sides, and in tapering more toward the ends of the test.

Occurrence.—Cushman reports that this species is rare in Colombia. Only a few specimens have been found in the Redbank at Atlantic Highlands; and in the lower New Egypt of the Clementon and Whitesville wells.

Figured specimen.—R 5114.

Genus SEABROOKIA H. B. Brady, 1890
SEABROOKIA STEWARTI n. sp.
Pl. 7, figs. 15,16

Test.—involute, much compressed, biconvex, more so on one side than on the other, oval in outline with a straight edge at the apertural end, axial periphery strongly acute with a narrow thin keel. *Wall.*—calcareous, smooth, finely perforate. *Chambers.*—2 to the whorl, added in planes of slightly less than 180°, the last formed chamber making up over $\frac{3}{4}$ of the test, hence it is this chamber that gives the characteristics of the test. *Sutures.*—flush with surface to very slightly depressed, semicircular. *Aperture.*—narrow, elliptical, with a short neck, surrounded by a distinct lip. Length 0.25 mm. Thickness 0.05 mm.

Remarks.—The species is identified by the small much compressed test and the characteristic aperture with a short neck and a distinct lip.

Occurrence.—This distinctive species is fairly common in the Redbank at Atlantic Highlands and New Egypt. It is present in the lower New Egypt of the Clementon and Whitesville wells.

Types.—Holotype (USNM 626469) and paratypes (P 81050 and R 5038) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Genus PULLENIA Parker and Jones, 1862
PULLENIA AMERICANA Cushman
Pl. 7, figs. 17,18

Pullenia americana Cushman, 1936, p. 76, pl. 13, figs. 4,5; 1944, p. 14, pl. 3, fig. 6; Cushman & Deaderick, 1944, p. 339, pl. 53, fig. 25; Cushman, 1946, p. 146, pl. 60, figs. 13,14; 1948, p. 265, pl. XXV, figs. 21a,b.

Pullenia quinqueloba Cushman (not Reuss), 1931, p. 57, pl. 10, figs. 4a,b; 1931, p. 313, pl. 36, figs. 3a,b; Jennings (not Reuss), 1936, p. 34, pl. 4, figs. 6a,b.

Remarks.—The Redbank species compare fairly well with the type material. It is identified by the planispiral, involute, compressed, somewhat umbilicate test; rounded axial periphery; 5–6 slightly inflated chambers that increase gradually in size; and the somewhat depressed slightly curved sutures.

Diameter 0.40 mm. Thickness 0.25 mm.

Occurrence.—In the Gulf Coast this species is found in the Taylor through the Navarro. Nine reports its presence in the Navesink of New Jersey. It is present in the Redbank at Atlantic Highlands. It is present also in the lower New Egypt of the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5115.

Family ORBULINIDAE
Genus GLOBIGERINA d'Orbigny, 1826
GLOBIGERINA INAEQUISPIRA Subbotina
Pl. 8, figs. 1–3

Globigerina inaequispira Subbotina, 1953, p. 69, pl. 6, figs. 1–4; Loeblich & Tappan, 1957, p. 181, pl. 49, figs. 2a–c, pl. 52, figs. 1,2, pl. 56, fig. 7, pl. 61, fig. 3, pl. 62, fig. 2.

Remarks.—This species is similar to *Globigerina triloculinoides* Plummer. It differs from this species by the less punctate surface and the presence of fine spines around the umbilical area.

Largest diameter 0.45 mm.

Occurrence.—Subbotina described this species from the Lower-Middle Eocene of Russia. Loeblich and Tappan have recorded it from the Hornerstown (Shingle Run), Vincentown, Salt Mountain, Nanafalia, Aquia, and Velasco formations. In the Hornerstown it is present at the Shingle Run and Crosswicks Creek localities and has been found in the Glendola well (301–308′) and Whitesville well (210–238′). It has

been observed in the Noxontown fauna of Delaware.

Types.—Figured hypotype R 5116.

GLOBIGERINA SPIRALIS Bolli
Pl. 7, figs. 19–21

Globigerina spiralis Bolli, 1957, p. 70, pl. 16, figs. 16–18; Loeblich & Tappan, 1957, p. 183, pl. 47, fig. 3, pl. 49, fig. 3, pl. 51, figs. 6–9, pl. 53, fig. 3.

Remarks.—This species is characterized by the rather high trochospiral test, the spiral side distinctly elevated, 5–6 chambers of the last whorl, globular chambers, and the depressed sutures. The coiling is random.

Diameter 0.20 to 0.30 mm.

Occurrence.—*Globigerina spiralis* Bolli was described from the Lower Lizard Springs of Trinidad. Loeblich and Tappan have recorded it from the Hornerstown (Shingle Run), Vincentown, Salt Mountain, and Aquia formations. In the Hornerstown it occurs at the Shingle Run and Crosswicks Creek localities. It also occurs in the Noxontown fauna from Middletown, Delaware. It is found in the Glendola well (301–308′) and the Whitesville (210–238′). It is present in the Hornerstown at Birmingham.

Types.—Figured hypotype R 5117.

GLOBIGERINA TRILOCULINOIDES
Plummer
Pl. 7, figs. 22–24

Globigerina triloculinoides Plummer, 1926, p. 134, pl. 8, figs. 10a–c; Jennings, 1936, p. 193, pl. 31, fig. 10; Glaessner, 1937, p. 382, pl. 4, fig. 33; Cushman, 1940, p. 72, pl. 12, figs. 15a,b; Toulmin, 1941, p. 607, pl. 82, fig. 3; Cushman & Todd, 1942, p. 43, pl. 8, figs. 1,2; Beck, 1943, p. 609, pl. 108, figs. 2,3; Kline, 1943, p. 59, pl. 6, figs. 12,13; Cushman, 1944, p. 48, pl. 8, fig. 4; Cooper, 1944, p. 353, pl. 54, figs. 12,13; Brotzen, 1958, p. 89, pl. 17, fig. 2; Weiss, 1955, p. 308, pl. 1, figs. 18–21; Haynes, 1956, p. 99, pl. 17, figs. 11,11b,15,15b; Bolli, 1957, p. 70, pl. 15, figs. 18–20; Loeblich & Tappan, 1957, p. 183, pl. 40 fig. 4, pl. 41, fig. 2, pl. 42, fig. 2, pl. 43, figs. 5,8,9, pl. 45, fig. 3, pl. 46, fig. 1, pl. 47, fig. 2, pl. 52, figs. 3–7, pl. 56, fig. 8, pl. 62, fig. 4; Troelsen, 1957, p. 129, pl. 30, fig. 4.

Remarks.—The distinguishing features of this species are the highly globose chambers, strongly reticulate surface, and the arched aperture with a definite lip.

Occurrence.—The species has a wide occurrence. Since it was described from the Midway of Texas by Plummer it subsequently has been frequently reported from Paleocene and Eocene beds in the Western and Eastern hemispheres. In New Jersey it occurs in the Vincentown and Hornerstown formations. In the Hornerstown it occurs at the Shingle Run and Crosswicks Creek localities. It has been found at the Permutit pit, Birmingham and in the basal Hornerstown at Contact Creek. It is present in the Clementon well (210′), Glendola well (301–313′), and the Whitesville well (210–281′). It also has been found in the Noxontown fauna of Delaware.

Types.—Figured hypotype R 5118.

Genus GLOBIGERINOIDES Cushman
1927
GLOBIGERINOIDES DAUBJERGENSIS
(Bronniman)
Pl. 8, figs. 4–6

Globigerina daubjergensis Bronnimann, 1953, p. 340, pl. 1; Bolli, 1957, p. 70, pl. 16, figs. 13–15; Troelsen, 1957, p. 128, pl. 30, figs. 1,2.
Globigerinoides daubjergensis Loeblich & Tappan, 1957, p. 184, pl. 40, figs. 1,8, pl. 41, fig. 9, pl. 42, figs. 6,7, pl. 43, fig. 1, pl. 44, figs. 7,8.

Remarks.—This diagnostic species is identified by the high trochospiral test with a pointed initial portion, finely spinose walls, subglobular chambers, generally 4 in the final whorl, deeply incised sutures, small umbilical aperture, and the supplementary apertures situated along the spiral suture. Random coiling is present.

Diameter 0.15 to 0.25 mm.

Occurrence.—This is a diagnostic species of the type Danian. Loeblich and Tappan have reported it from the Midway of Texas and its equivalents on the Atlantic and Gulf Coasts. It occurs in the basal Hornerstown in the Clementon well (210′). It also occurs in the Whitesville well (238–281′).

Types.—Figured hypotype R 5119.

Family HANTKENINIDAE
Genus GLOBIGERINELLA Cushman,
1927
GLOBIGERINELLA MESSINAE
SUBCARINATA Bronnimann
Pl. 8, figs. 9,10

Globigerinella messinae subcarinata Bronnimann, 1952, p. 44, pl. 1, figs. 10,11, text fig. 21.

Remarks.—The species is easily identified

by the small, compressed test, lobate equatorial periphery, and the rather deep radial sutures. The Redbank species are identical except that they are slightly smaller in size.

Diameter 0.28 to 0.30 mm.

Occurrence.—It is restricted to the uppermost *Abathomphalus mayaroensis* zone of the Maestrichtian of Trinidad. It is present in Redbank at Atlantic Highlands and New Egypt, and in the lower New Egypt in the Whitesville and Glendola wells.

Types.—Figured hypotype R 5120.

Genus BIGLOBIGERINELLA Lalicker, 1948

BIGLOBIGERINELLA BIFORAMINATA (Hofker)

Pl, 8, figs. 7,8

Globigerinella biforaminata Hofker, 1956, p. 53, figs. 2,5.
Globigerina biforaminata Hofker, 1956, p. 76, pl. 9, figs. 68a–c, pl. 10, figs. 71a–c.
Globigerinella aspera Cushman, 1931, p. 59, pl. 11, figs. 5a,b; Jennings, 1936, p. 36, pl. 4, fig. 11; Brotzen, 1936, p. 170, pl. 13, figs. 2a–c, text fig. 62.

Remarks.—The species is identified by the nearly involute planispiral test, 6–7 spherical to subspherical chambers of the last whorl, heavily spinose walls, and depressed radial sutures. All stages of the apertural development were found, from the equatorial position, to the double extra-umbilical and to the final paired chambers with single apertures. The apertures are bordered by a narrow lip.

Diameter 0.30 mm.

Occurrence.—The species is found in the Maestrichtian of Europe and the Navarro of Tennessee. Jennings has reported this form from the Mt. Laurel and Navesink formations of New Jersey. It is common in the Navesink and in the Redbank at Atlantic Highlands and New Egypt. It occurs commonly in the lower New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5121.

Family GLOBOROTALIIDAE
Genus GLOBOROTALIA Cushman, 1927
GLOBOROTALIA AEQUA Cushman and Renz

Pl. 8, figs. 11–13

Globorotalia crassata var. *aequa* Cushman & Renz, 1942, p. 12, pl. 3, figs. 3a–c; Cushman & Todd, 1942, p. 44, pl. 8, figs. 7–9.
Globorotalia aequa Cushman & Renz, 1957, p. 12, pl. 3, figs. 3a–c. Loeblich & Tappan, 1957, p. 186, pl. 46, figs. 7,8, pl. 50, fig. 6, pl. 55, fig. 8, pl. 59, fig. 6, pl. 60, fig. 3, pl. 64, fig. 4.

Remarks.—The species is characterized by the strongly umbilico-convex test, 3–4 chambers of the last whorl, relatively large last chamber, and the strongly depressed sutures of the umbilical side. The Hornerstown species shows a preference for sinistral coiling.

Diameter up to 0.45 mm.

Occurrence.—*Globorotalia aequa* Cushman and Renz was described from the Soldado formation in Trinidad. Bolli reports it from the Lizard Springs formation of Trinidad and Loeblich and Tappan record it from the Paleocene and lower Eocene of the Atlantic and Gulf Coastal Plains. In the Hornerstown it occurs at the Shingle Run, Crosswicks Creek, and Permutit pit localities. It is present in the Glendola well (301–313′) and the Whitesville well (210–238′). It also is present in the Noxontown fauna.

Types.—Figured hypotype R 5122.

GLOBOROTALIA ANGULATA (White)

Pl. 8, figs. 14–16

Globigerina angulata White, 1928, p. 191, pl. 27, figs. 13a–c.
Globorotalia angulata Bolli, 1957, p. 74, pl. 17, figs. 7–9; Loeblich & Tappan, 1957, p. 187, pl. 45, fig. 7, pl. 48, figs. 2a–c, pl. 50, fig. 4, pl. 55; fig. 2,6,7, pl. 58, figs. 2a–c, pl. 64, fig. 5.

Remarks.—The species is identified by the subangular chambers, 5 in the last whorl, acute axial periphery, deep narrow umbilicus, and strongly depressed sutures on the umbilical side.

Largest diameter 0.45 mm.

Occurrence.—The species is found in the Velasco, lower Lizard Springs, Hornerstown, Vincentown, Aquia, Salt Mountain formations, and the Matthews Landing marl member of the Naheola formation. In the Hornerstown it is present at the Shingle Run and Crosswicks Creek localities. It has been found in the Glendola well (301–313′) and Whitesville well (210–238′), and in the Noxontown fauna.

Types.—Figured hypotype R 5123.

GLOBOROTALIA APANTHESMA Loeblich and Tappan
Pl. 8, figs. 17–19

Globorotqlia apanthesma Loeblich & Tappan, 1957, p. 187, pl. 48, fig. 1, pl. 55, fig. 1, pl. 59, fig. 1, pl. 58, fig. 4.

Remarks.—The Hornerstown species compares well with holotype and paratype material. The species is identified by the very low trochospiral, strongly umbilico-convex test, acute axial periphery, fairly wide, deep umbilicus, and heavily spinose surface.

Largest diameter 0.45 mm.

Occurrence.—Loeblich and Tappan described this species from the Aquia, Salt Mountain, and Vincentown formations. It is present in the Hornerstown at Crosswicks Creek and in the Glendola well (301–302′). The species has been observed in the Noxontown fauna.

Types.—Figured hypotype R 5124.

GLOBOROTALIA COMPRESSA (Plummer)
Pl. 8, figs. 20–22

Globigerina compressa Plummer, 1926, p. 135, pl. 8, fig. 11; Glaessner, 1937, p. 382, pl. 4, fig. 32; Kline, 1943, p. 58, pl. 6, figs. 5,6; Brotzen, 1948, p. 90; Troelsen, 1957, p. 129, pl. 30, fig. 5.
Globorotalia compressa Bronnimann, 1952, p. 25, pl. 2, figs. 19–24; Bolli, 1957, p. 77, pl. 20, figs. 21–23; Loeblich & Tappan, 1957, p. 188, pl. 40, figs. 5a–c, pl. 41, fig. 5, pl. 42, figs. 5a–c, pl. 44, figs. 9,10.

Remarks.—The species is identified by the very low trochospiral, somewhat compressed, biconvex test, generally 5 chambers of the last whorl, smooth walls, distinctly depressed sutures, and extraumbilical-umbilical aperture with a definite lip that is directed toward the umbilicus. The Hornerstown species are identical with Plummer's figures and material from the Wills Point formation. A comparison with the Swedish Paleocene material shows them to be conspecific.

Diameter 0.20 to 0.30 mm.

Occurrence.—The species was described from the upper Midway of Texas by Plummer. Loeblich and Tappan have reported its occurrence in association with *Globigerinoides daubjergensis* (Bronnimann) as diagnostic of a Danian age. They recorded it from the Midway of Texas and its equivalents in the Atlantic and Gulf Coastal plains. It has been found in the basal Hornerstown at Contact Creek. It has been observed in association with *G. daubjergensis* in the Clementon well (210′) and the Whitesville well (238–281′).

Types.—Figured hypotype R 5125.

GLOBOROTALIA CONVEXA Subbotina
Pl. 9, figs. 13–15

Globorotalia convexa Subbotina, 1953, p. 209, pl. 17, figs. 2a–c, 3a–c; Loeblich & Tappan, 1957, p. 188, pl. 48, fig. 4, pl. 50, fig. 7, pl. 53, figs. 6–8, pl. 57, figs. 5–6, pl. 61, fig. 4, pl. 63, fig. 4.

Remarks.—The species is characterized by a small, low trochospiral biconvex test, with the surface covered by numerous spines, a closed umbilicus, and 5–6 chambers in the final whorl, gradually increasing in size.

Largest diameter 0.20 mm.

Occurrence.—*Globorotalia convexa* Subbotina was described from the lower Tertiary of Russia. It subsequently has been identified from the Hornerstown (Shingle Run), Vincentown, Aquia, Salt Mountain, Nanafalia, and Velasco formations by Loeblich and Tappan. It occurs in the Hornerstown at the Shingle Run and Crosswicks Creek localities. It is present in the Glendola well (301–308′) and Whitesville well (210–238′).

Types.—Figured hypotype R 5126.

GLOBOROTALIA ELONGATA Glaessner
Pl. 9, figs. 4–6

Globorotalia pseudoscitula var. *elongata* Glaessner, 1937, p. 3, tf. 3d–f.
Globorotalia elongata Bolli, 1957, p. 77, pl. 20, figs. 11–13; Loeblich & Tappan, 1957, p. 189, pl. 45, fig. 5, pl. 46, fig. 5, pl. 48, fig. 5, pl. 49, fig. 7, pl. 54, figs. 1–5, pl. 59, fig. 4, pl. 60, fig. 9, pl. 63, fig. 2.
Globorotalia compressa Jennings, 1936, p. 193, pl. 4, fig. 8; Toulmin 1941, p. 607, pl. 82, figs. 1,2.

Remarks.—Distinguishing characteristics are the very low trochospiral, compressed test, subacute to acute axial periphery, smooth surface and distinctly depressed sutures.

Diameter 0.30 to 0.55 mm.

Occurrence.—This species was described from the lower Tertiary of the Caucasus. Loeblich and Tappan have reported it from the Paleocene and lower Eocene of the At-

lantic and Gulf Coastal Plains. Jennings first figured it as *Globigerina compressa* Plummer from the Hornerstown. It differs from this species by the greater increase in chamber size and a more angular axial periphery. In the Hornerstown it is present at the Shingle Run, Crosswicks Creek, and Permutit pit localities. It is found in the Glendola well (301–313′) and the Whitesville well (210–238′). The species occurs in the Noxontown assemblage of the Delaware.

Types.—Figured hypotype R 5127.

GLOBOROTALIA IMITATA Subbotina
Pl. 9, figs. 7–9

Globorotalia imitata Subbotina, 1953, p. 206, pl. 16, figs. 14–16; Loeblich & Tappan, 1957, p. 190, pl. 44, figs. 3a–c, pl. 45, figs. 6a–c, pl. 54, figs. 8,9, pl. 59, fig. 5, pl. 63, fig. 3.

Remarks.—The species is characterized by a small low trochospiral compressed test, smooth surface, depressed sutures, and the somewhat ovate, wider than high chambers. It is similar to *Globorotalia compressa* (Plummer) from which it differs by the wider, less compressed chambers and the umbilico-convex test.

Diameter up to 0.22 mm.

Occurrence.—*Globorotalia imitata* was described by Subbotina from the Lower Tertiary of Russia. It occurs in beds of Paleocene and Early Eocene age in the Atlantic and Gulf Coastal Plains. In the Hornerstown this species is present at the Shingle Run and Crosswicks Creek localities. It has been found in the Clementon well (210′), Glendola well (301–302′), and Whitesville well (210–238′). It also occurs in the Noxontown fauna.

Types.—Figured hypotype R 5128.

GLOBOROTALIA PERCLARA Loeblich and Tappan
Pl. 9, figs. 1–3

Globorotalia perclara Loeblich & Tappan, 1957, p. 191, pl. 40, fig. 7, pl. 41, fig. 8, pl. 42, fig. 4, pl. 45, fig. 11, pl. 46, fig. 3, pl. 47, fig. 6, pl. 50, fig. 1, pl. 54, figs. 6,7, pl. 57, figs. 3,4, pl. 60, fig. 5.

Remarks.—The Hornerstown forms are identical with holotype and paratype material. They are distinguished by a low trochospiral test, distinctly convex umbilical side, strongly depressed sutures, and the depressed spiral suture of the final whorl. Rather coarse spines are generally present on the umbilical side, while the spiral side may remain smooth or be partially covered with spines.

Diameter up to 0.35 mm.

Occurrence.—*Globorotalia perclara* was described by Loeblich and Tappan from the Paleocene and lower Eocene of the Atlantic and Gulf Coastal Plains. It is present in the Hornerstown at Shingle Run, Crosswicks Creek, and Permutit pit, Birmingham. It is found in the Clementon well (210′), Glendola well (301–308′) and the Whitesville well (210–260′), It also has been observed in the Noxontown fauna.

Types.—Figured hypotype R 5129.

GLOBOROTALIA PSEUDOBULLOIDES (Plummer)
Pl. 9, figs. 19–21

Globigerina pseudobulloides Plummer, 1926, p. 133, pl. 8; figs. 9a–c; Glaessner, 1937, p. 382, pl. 4, fig. 31; Cushman, 1940, p. 72, pl. 12, fig. 16; Cushman & Todd, 1942, p. 43, pl. 8, figs. 3,4; Kline, 1943, p. 58, pl. 6, figs. 9–11; Haynes, 1956, p. 99, pl. 17, figs. 12a,b; Troelsen, 1957, p. 128, pl. 30, figs. 6–8.

Globorotalia pseudobulloides Bolli, 1957, p. 73, pl. 17, figs. 19–21; Loeblich & Tappan, 1957, p. 192, pl. 40, figs. 3a–c, 9a–c, pl. 41, figs. 1a–c, pl. 42, figs. 3a–c, pl. 43, figs. 3,4, pl. 44, figs. 4–6, pl. 45, figs. 1,2, pl. 46, fig. 6.

Remarks.—The species is characterized by the low trochospiral, biconvex test, generally 5 chambers of the last whorl, distinctly punctate walls, and the extraumbilical-umbilical aperture with a lip.

Diameter 0.30 to 0.40 mm.

Occurrence.—The species was described from the Midway of Texas by Plummer. Loeblich and Tappan have reported it in beds of Paleocene age from the Atlantic and Gulf Coastal Plains. It is found in the Thanetian of England. Bronnimann has recorded its presence in the type Danian of Denmark. In the Hornerstown it is present at the NJT 11 locality on Crosswicks Creek, at the Permutit pit, Birmingham, and in the basal Hornerstown along Contact Creek. It has been found in the Clementon well (210′), Glendola well (312–313′), and the Whitesville well (225–281′). It has been observed in the Noxontown fauna of Delaware.

Types.—Figured hypotype R 5130.

GLOBOROTALIA REDBANKENSIS n. sp.
Pl. 9, figs. 16–18

Test.—very low trochospiral, compressed, spiral side moderately convex, umbilical side slightly concave. Equatorial periphery, elongate. Axial periphery rounded to subacute. *Wall.*—calcareous, perforate, smooth. *Chambers.*—rather strongly compressed; about 15 arranged in 2½ whorl. The 6 chambers of the last whorl increase rapidly in size. *Sutures.*—spiral side: radial, depressed. Umbilical side: radial, depressed. *Umbilicus.*—narrow, deep open. *Aperture.*—low arch, interiomarginal, extraumbilical-umbilical with a distinct, rather wide lip. The apertures of the previous chambers remain open into the umbilicus. *Coiling.*—random. Largest diameter 0.20 to 0.40 mm. Average 0.30 mm.

Remarks.—This species closely resembles *Globorotalia elongata* Glaessner. It is distinguished from this species by the more rounded axial periphery, the convex spiral side with radial sutures, the deep narrow umbilicus, and the distinct, rather wide apertural lip.

Occurrence.—The species is present in the Redbank at Atlantic Highlands and New Egypt and in the Redbank in the Clementon, Whitesville, and Glendola wells.

Types.—Holotype (USNM 626470) and paratypes (P 81051 and R 5039) from the Sandy Hook member of the Redbank formation, locality NJK-103.

GLOBOROTALIA MONMOUTHENSIS n. sp.
Pl. 9, figs. 22–24

Test.—very low trochospiral, nearly planispiral in appearance. Equatorial periphery strongly lobate. Axial periphery rounded. *Wall.*—calcareous, finely perforate, covered with short minute spines. *Chambers.*—inflated, globular; about 15 arranbed in 2½ whorls. The 5, occasionally 6, chambers of the final whorl increase rather rapidly in size; the last two make up over ½ of the test. *Sutures.*—spiral side: oblique in early stages to straight in adult stages, depressed. Umbilical side: radial, depressed. *Umbilicus.*—narrow, deep. *Aperture.*—a low arch with a distinct lip; interiomarginal, extraumbilical-umbilical. *Coiling.*—random. Diameter 0.20 to 0.25 mm.

Remarks.—This species is similar to *Globorotalia compressa* (Plummer). It differs in the lack of the compressed chambers, the more rapid increase in chamber size and the presence of fine minute spines.

Occurrence.—The species occurs in the Redbank at Atlantic Highlands and New Egypt. It is present in the Redbank and lower New Egypt intervals in the Clementon, Whitesville and Glendola wells.

Types.—Holotype (USNM 626471) and paratypes (P81052 and R 5040) from the Sandy Hook member of the Redbank formation, locality NJK-103.

GLOBOROTALIA CROSSWICKSENSIS n. sp.
Pl. 10, figs. 7–9

Test.—very low trochospiral, spiral side slightly to distinctly convex, umbilical side strongly convex. Equatorial periphery. Lobate. Axial periphery sharply acute, with a keel ornamented with rather coarse spines. *Wall.*—calcareous, perforate, surface covered with numerous fine spines. *Chambers.*—angular, very slightly inflated; about 13–15 arranged in 2½ whorls. The 5, occasionally 6, chambers of the last whorl increase somewhat rapidly in size. *Sutures.*—spiral side: strongly curved, even with surface. Umbilical side: radial, distinctly depressed. *Umbilicus.*—narrow, deep, open. *Aperture.*—low arch with a thin lip; interiomarginal, extraumbilical-umbilical. *Coiling.*—random. Diameter 0.35 to 0.40 mm.

Remarks.—The species is similar to *Globorotalia trichotrocha* Loeblich and Tappan. It is distinguished from this species in the presence of a keel, 5 chambers in final whorl, more rapid increase in chamber size, more strongly convex umbilical side, and the non-depressed sutures on the spiral side.

Occurrence.—This species is present in the Hornerstown at the Crosswicks Creek localities and has been observed in the Glendola well (307–308′).

Types.—Holotype (USNM 626472) and paratypes (P 81053 and R 5041) from the Hornerstown formation, locality NJT-11.

GLOBOROTALIA PSEUDOMENARDII Bolli
Pl. 9, figs. 10–12

Globorotalia pseudomenardii Bolli, 1957, p. 77, pl. 20, figs. 14–17; Loeblich & Tappan, 1957, p. 193, pl. 45, fig. 10, pl. 47, fig. 4, pl. 49, fig. 6,

pl. 54, figs. 10–13, pl. 59, fig. 3, pl. 60, fig. 8, pl. 63, fig. 1.

?Globorotalia pseudoscitula Glaessner, 1937, p. 32, tf. 3a–c.

Globorotalia membranacea Toulmin, 1941, p. 608, pl. 82, figs. 4,5.

Remarks.—Distinguishing characteristics of this species are the very low trochospiral test, angular axial periphery with a distinct keel, smooth walls, strongly compressed chambers, strongly curved sutures on the spiral side and radial sutures on the umbilical side.

Largest diameter 0.40 mm.

Occurrence.—The species was described by Bolli from the lower Lizard Springs of Trinidad. Loeblich and Tappan have recorded it from the Paleocene and Eocene of the Atlantic and Gulf Coastal Plains. It also occurs in the lower Tertiary of the Caucasus. In the Hornerstown *Globorotalia pseudomenardii* Bolli occurs at the Shingle Run and Crosswicks Creek localities. It is found in the Glendola well (301–308′) and the Whitesville well (210–238′), and in the Noxontown fauna.

Types.—Figured hypotype R 5131.

GLOBOROTALIA REISSI Loeblich and Tappan
Pl. 10, figs. 4–6

Globorotalia reissi Loeblich & Tappan, 1957, p. 194, pl. 50, figs. 3a–c, pl. 58, fig. 3; pl. 60, figs. 7a–c.

Remarks.—The diagnostic features of this species are the moderately high trochospiral, biconvex test, depressed sutures, and a gradual increase in chamber size. The species is similar to *Globorotalia perclara* Loeblich and Tappan, from which it differs by the smaller size, distinctly convex spiral side, gradual increase in chamber size, nondepressed spiral suture, and less inflated chambers.

Diameter 0.15 to 0.17 mm.

Occurrence.—Loeblich and Tappan have described and recorded this species from the Paleocene and lower Eocene of the Atlantic and Gulf Coastal Plains. It is found in the Hornerstown at the Shingle Run and Crosswicks Creek localities, and in the Noxontown fauna.

Types.—Figured hypotype R 5132.

GLOBOROTALIA STRABOCELLA Loeblich and Tappan
Pl. 10, figs. 10–12

Globorotalia strabocella Loeblich & Tappan, 1957, p. 195, pl. 61, fig. 6.

Remarks.—The Hornerstown forms compare well with holotype and paratype material. Diagnostic characteristics are the low trochospiral, umbilico-convex test, rounded axial periphery, moderately wide, deep umbilicus, and the distinctly depressed sutures. The Hornerstown specimens exhibit random coiling.

Diameter 0.35 to 0.42 mm.

Occurrence.—This species was described from the Nanafalia and Vincentown forma-

EXPLANATION OF PLATE 11

FIGS. *1–3—Globotruncana leupoldi* Bolli. *1*, Umbilical view, showing tegilla and infralaminal and intralaminal accessory apertures. *2*, Edge view. *3*, Spiral view. From the Redbank formation. ×80.

4,5—Anomalinoides acuta (Plummer). *4*, Spiral view. *5*, Umbilical view. From the Hornerstown formation. ×98.

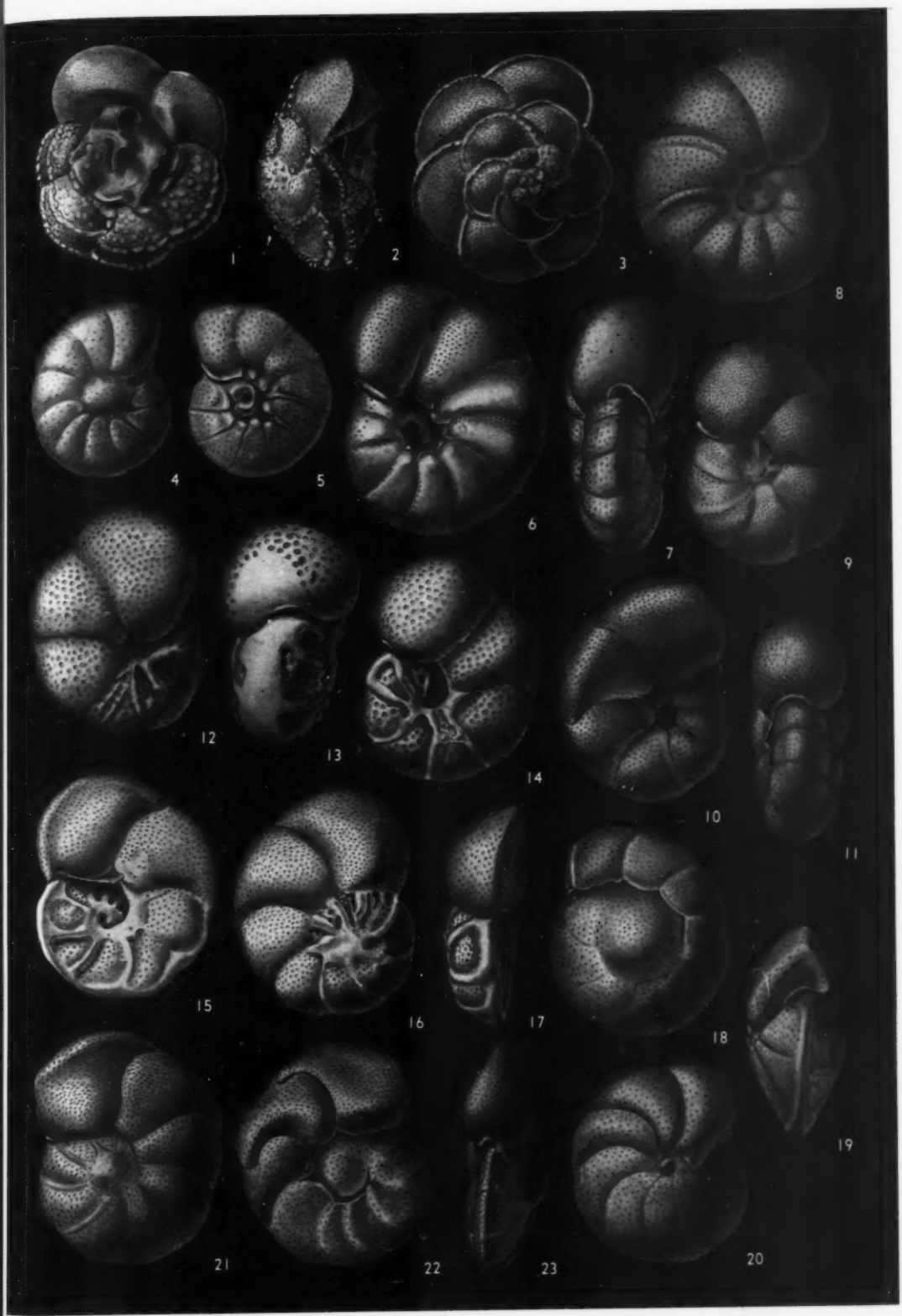
6–8—Anomalinoides midwayensis (Plummer). *6*, Umbilical view, showing aperture and umbilical lips. *7*, Edge view, showing extraumbilical-umbilical aperture and compressed test. *8*, Spiral view. From the Redbank formation. ×98.

9–11—Anomalinoides highlandicus n. sp. Holotype. *9*, Spiral view. *10*, Umbilical view, showing aperture, apertural lips and umbilical lips. *11*, Edge view, showing biconvex compressed test and extraumbilical-umbilical aperture. From the Redbank formation. ×80.

12–14—Anomalinoides longi (McLean). *12*, Spiral view. *13*, Edge view, showing extraumbilical-umbilical aperture. *14*, Umbilical view, showing aperture, coarsely perforate walls, and the limbate sutures of the early chambers. From the Hornerstown formation. ×61.

15–17—Cibicides neelyi Jennings. *15*, Umbilical view, showing aperture, apertural lip, and growth of shell material around umbilicus. *16*, Spiral view, showing the limbate sutures of early portion of test. *17*, Edge view. From the Hornerstown formation. ×43.

18–23—Cibicides harperi (Sandidge). Specimens illustrate variation of this species in New Jersey. *18,22*, Umbilical views. *19,23*, Edge views. *20,21*, Spiral views. From the Redbank formation. ×80.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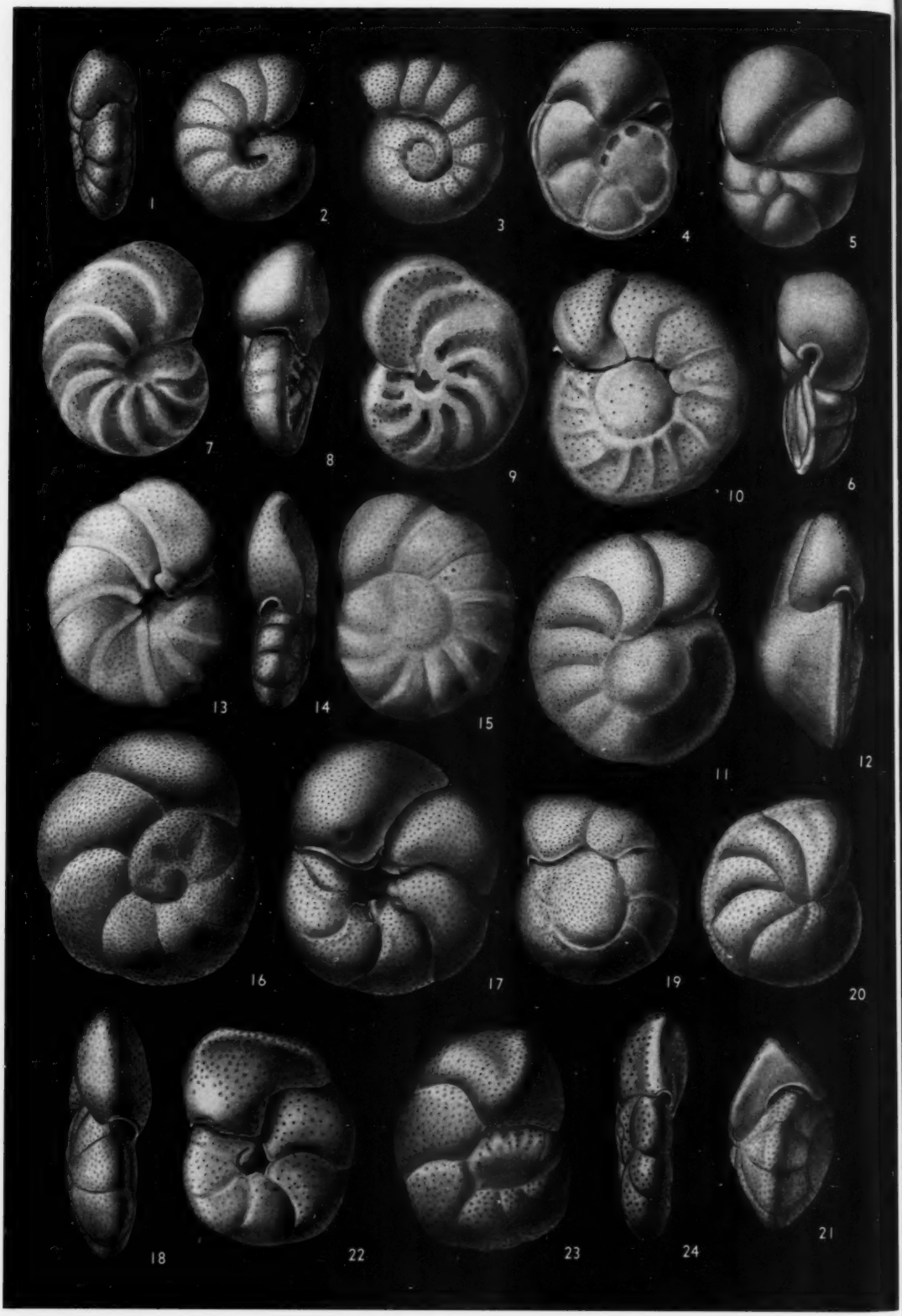
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tions. It occurs in the Hornerstown at Crosswicks Creek.

Types.—Figured hypotype R 5133.

GLOBOROTALIA TRICHOTROCHA Loeblich and Tappan
Pl. 10, figs. 1–3

Globorotalia trichotrocha Loeblich & Tappan, 1957, p. 195, pl. 50, fig. 5, pl. 57, figs. 1,2.

Remarks.—The paratypes of this species are from the Hornerstown at the Shingle Run locality. The diagnostic features are the small, low trochospiral, biconvex test, subacute, axial periphery, six chambers in the final whorl that gradually increase in size around a deep narrow umbilicus and the surface covered with numerous spines.

Largest diameter 0.30 mm.

Occurrence.—The species is present in the Hornerstown at the Crosswicks Creek locality and has been found in the Glendola well (301–308′) and Whitesville well (225–238′).

Types.—Figured hypotype R 5134.

Family GLOBOTRUNCANIDAE
Genus RUGOGLOBIGERINA Bronnimann, 1952
RUGOGLOBIGERINA JERSEYENSIS n. sp.
Pl. 10, figs. 19–21

Test—very low trochospiral, compressed, spiral side slightly convex, umbilical side somewhat concave. Equatorial periphery strongly lobate, elongate. Axial periphery rounded to subacute. *Wall.*—calcareous, perforate, spinose; the earlier chambers rugose, produced peripherally into spine-like extensions, the last few chambers more evenly spinose, the ultimate chamber very lightly so or smooth. *Chambers.*—ovate, about 12 arranged in 2½–3 whorls. The 4 chambers of the final whorl increase rapidly in size, the last 2 make up about ⅔ of the test. *Sutures.*—spiral side: slightly curved, depressed. Umbilical side: radial, depressed. *Umbilicus.*—small, shallow. *Aperture.*—primary apertures interiomarginal, umbilical covered by tegilla which extend over the umbilicus, and with accessory infralaminal apertures. *Coiling.*—dominantly dextral. Largest diameter 0.30 to 0.35 mm. up to 0.45 mm.

Remarks.—This species differs from *Globotruncana citae* Bolli in the more rapid increase in chamber size and the more distinctly lobate equatorial periphery.

Occurrence.—This species is present in the Redbank at Atlantic Highlands and New Egypt. It is present in the lower New Egypt and Redbank intervals in the Glendola, Whitesville, and Clementon wells.

Types.—Holotype (USNM 626473) and paratypes (P 81054 and R 5042) from the Sandy Hook member of the Redbank formation, locality NJK-103.

EXPLANATION OF PLATE 12

FIGS. *1–3—Anomalinoides pseudowelleri* n. sp. Holotype. *1*, Edge view, showing compressed test and extraumbilical-umbilical aperture. *2*, Umbilical view, showing small umbilicus with numerous umbilical lips. *3*, Spiral view, showing the depressed spiral suture. From the Hornerstown formation. ×61.

4–6—Cibicides marylandicus Shifflett. *4*, Umbilical view, showing the restricted aperture. *5*, Spiral view. *6*, Edge view, showing planoconvex test and aperture. From the Hornerstown tion. ×61.

7–9—Cibicides simplex Brotzen. *7*, Spiral view. *8*, Edge view, showing extraumbilical-umbilical aperture. *9*, Umbilical view. From the Hornerstown formation. ×80.

10–12—Cibicides succedens Brotzen. *10*, Umbilical view, showing aperture. *11*, Spiral view, showing prominent plug. *12*, Edge view showing extraumbilical-umbilical aperture. From the Hornerstown formation. ×98.

13–15—Cibicides compressa n. sp. Holotype. *13*, Umbilical view, showing aperture, apertural lips and umbilical lips. *14*, Edge view, showing the strongly compressed test and extraumbilical-umbilical aperture. *15*, Spiral view. From the Hornerstown formation. ×98.

16–18—Planulina correcta (Carsey). *16*, Spiral view. *17*, Umbilical view, showing aperture, apertural lips and umbilical lips. *18*, Edge view, showing compressed test and extra-umbilical-umbilical aperture. From the Redbank formation. ×98.

19–21—Cibicidoides hilgardi (Garrett). *19*, Umbilical view, showing aperture and large umbilical plug. *20*, Spiral view. *21*, Edge view, showing strongly biconvex test and extraumbilical-umbilical aperture. From the Hornerstown formation. ×43.

22–24—Planulina multipunctata Bandy. *22*, Umbilical view, showing aperture and coarsely perforate walls. *23*, Spiral view. *24*, Edge view, showing strongly compressed test and extra-umbilical-umbilical aperture. From the Redbank formation. ×61.

RUGOGLOBIGERINA REICHELI PUSTULATA
Bronnimann
Pl. 10, figs. 13–15

Rugoglobigerina reicheli pustulata Bronnimann, 1952, p. 20, pl. 2, figs. 7–9, text figs. 6,7.
Rugoglobigerina reicheli hexacamerata Bronnimann, 1952, p. 23, pl. 2, figs. 10–12, text fig. 8.

Remarks.—This species is distinguished by the small, low trochospiral test, slightly depressed spiral side, and the 5–6 subglobular chambers of the last whorl.

Diameter 0.25 to 0.39 mm.

Occurrence.—The species was described by Bronnimann from Trinidad where it occurs in the upper Campanian and Maestrichtian. It is common in the Redbank at Atlantic Highlands and present at New Egypt. It occurs commonly in the lower New Egypt in the the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5135.

RUGOGLOBIGERINA RUGOSA RUGOSA
(Plummer)
Pl. 10, figs. 16–18

Globigerina rugosa Plummer, 1926, p. 38, pl. 2, figs. 10a–d.
Rugoglobigerina rugosa rugosa Bronnimann, 1952, p. 28, text figs. 11–13.

Remarks.—Distinguishing characteristics of this species are the large trochospiral test and the strong rugosities.

Diameter 0.40 to 0.55 mm.

Occurrence.—In Trinidad this species ranges through beds of Campanian and Maestrichtian age. It occurs rarely in the Redbank at Atlantic Highlands and New Egypt; and in the lower New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5136.

Genus GLOBOTRUNCANA Cushman, 1927
GLOBOTRUNCANA CONTUSA (Cushman)
Pl. 10, figs. 25,26

Globotruncana arca var. *contusa* (Cushman), 1946, p. 150, pl. 62, figs. 6a,b.
Globotruncana conica var. *plicata* White, 1928, p. 285, pl. 38, figs. 8a–c; Cushman & Renz, 1947, p. 50, pl. 12, fig. 13.
Globotruncana contusa (Cushman) Cita, 1948, p. 150, pl. 3, figs. 6a–c; Bolli, 1951, p. 196, pl. 34, figs. 7–9; Troelsen, 1955, p. 80, text fig. 2.

Remarks.—The species is identified by the very high spiroconvex test. acute axial periphery, and the concave chamber walls.

Diameter 0.60 mm.

Occurrence.—This species occurs in the Maestrichtian of Mexico, Trinidad, Italy, and Denmark. It is rare in the Redbank at Atlantic Highlands. It also occurs in the Navesink formation.

Types.—Figured hypotype R 5137.

GLOBOTRUNCANA LEUPOLDI Bolli
Pl. 11, figs. 1–3

Globotruncana leupoldi Bolli, 1944, p. 235, text fig. 1, figs. 25,26, pl. 9, fig. 17.

Remarks.—The Redbank and New Egypt species compare well with specimens of *Globotruncana leupoldi* collected from the Kemp clay of Texas. It is identified by the double keeled spiral-convex test, lobate equatorial periphery, and small umbilicus.

Diameter up to 0.60 mm.

Occurrence.—This species is present in the Redbank at Atlantic Highlands and New Egypt. It also is present in the lower New Egypt in the Whitesville, Glendola, and Clementon wells.

Types.—Figured hypotype R 5138.

GLOBOTRUNCANA MONMOUTHENSIS n. sp.
Pl. 10, figs. 22–24

Test.—single keeled, very low trochospiral, strongly umbilico-convex. Equatorial periphery slightly lobate. Axial periphery acute. *Wall.*—calcareous, perforate; covered with numerous heavy spines on umbilical side; nearly smooth on spiral side. *Chambers.*—angular truncate, 5–6 in final whorl. Increasing gradually in size as added. *Sutures.*—spiral side: gently curved, beaded, raised. Umbilical side: slightly curved somewhat depressed. *Umbilicus.*—small, narrow, deep. *Apertures.*—primary apertures interiomarginal, umbilical covered by tegilla, and with infralaminal and intralaminal accessory apertures. *Coiling*—dominantly dextral. Diameter up to 0.60 mm.

Remarks—This species is similar to *Globotruncana andori* De Klase. It differs from this species in its fewer chambers in the final whorl and the numerous heavy spines that cover the umbilical side.

Occurrence.—The species occurs commonly in the Navesink formation. It is less common in the Redbank at Atlantic Highlands and New Egypt. It also is found in the lower New Egypt in the Whitesville, Glendola, and Clementon wells.

Types.—Holotype (USNM 626474) and paratypes (P 81055 and R 5043) from the Sandy Hook member of the Redbank formation, locality NJK-103.

Family ANOMALINIDAE
Genus ANOMALINOIDES Brotzen, 1942
ANOMALINOIDES ACUTA (Plummer)
Pl. 11, figs. 4,5

Anomalina ammonoides (Reuss) var. *acuta* Plummer, 1927, p. 149, pl. 10, fig. 2.
Anomalina acuta Toulmin, 1941, p. 608, pl. 82, figs. 9,10; Cushman & Renz, 1942, p. 12, pl. 3, fig. 6; Kline, 1943, p. 59, pl. 5, figs. 3,4; Cooper, 1944, p. 353, pl. 54, figs. 3–5; Cushman & Todd, 1946, p. 64, pl. 11, figs. 13,14; Brotzen, 1948, pl. 87, pl. 14, fig. 2.

Remarks.—This species is distinguished by the numerous chambers, much compressed test, limbate sutures, and the distinct umbilical areas.

Diameter 0.35 mm.

Occurrence.—The species is found in the Midway of Texas, Mississippi, Illinois, and Arkansas. It also occurs in the Salt Mountain limestone of Alabama, Soldado formation of Trinidad, and the Paleocene of Sweden. In the Hornerstown this is a rare species. It is found at Shingle Run and Crosswicks Creek localities and in the Clementon well (210′).

Types.—Figured hypotype R 5139.

ANOMALINOIDES LONGI (McLean)
Pl. 11, figs. 12–14

Anomalina longi McLean, 1952, p. 11, pl. 2, figs. 9–12.
Gavelinella danica Hofker, 1955, p. 11, pl. 1.

Remarks.—Diagnostic features of this species are the large test with highly inflated chambers; depressed, limbate sutures, and coarsely perforate walls. The species differs from *Anomalinoides danica* Brotzen by the less concave umbilical side and by the less strongly curved sutures of this side. The Hornerstown forms are slightly smaller but otherwise agree in all aspects with the type material.

Diameter 0.70 mm.

Occurrence.—This is a very abundant species in the Vincentown. In the Hornerstown it is common at the Shingle Run locality. It is present in the Glendola well (301–302′).

Types.—Figured hypotype R 5140.

ANOMALINOIDES MIDWAYENSIS (Plummer) Brotzen
Pl. 11, figs. 6–8

Truncatulina midwayensis Plummer, 1927, p. 141, pl. 9, fig. 7, pl. 15, fig. 3.
Anomalina midwayensis Cushman, 1940, p. 73, pl. 12, fig. 18; Kline, 1943, p. 60, pl. 6, figs. 17,18; Cooper, 1944, p. 354, pl. 54, figs. 15–17; Cushman & Todd, 1946, p. 64, pl. 11, figs. 18,19.
Anomalinoides midwayensis Brotzen, 1948, p. 88, pl. 14, fig. 3.

Remarks.—The species is distinguished by the moderately compressed, biconvex test; 9–10 chambers of the final whorl; the curved raised, limbate sutures that taper toward the periphery; and the interiomarginal-umbilical to extraumbilical aperture with a narrow lip and distinct umbilical lips. In some specimens the last suture tends to be depressed.

Diameter 0.40 to 0.50 mm.

Occurrence.—This is the first record of this species from the Cretaceous. The species is present but not common in the Redbank at Atlantic Highlands.

Types.—Figured hypotype R 5141.

ANOMALINOIDES PINGUIS Jennings

Anomalina pinguis Jennings, 1936, p. 37, pl. 5 fig. 1; Cushman, 1944, p. 16, pl. 3, fig. 15.
Anomalina grosserugosa Plummer (not Gümbel), 1931, p. 201, pl. 14, figs. 9a–c.

Remarks—The species is distinguished by the nearly planispiral, biconvex test, coarsely punctate walls slightly curved sutures, limbate in early portion, depressed in later portions. The aperture is interiomarginal-umbilical to extraumbilical, extending onto the spiral side, with a narrow peripheral lip and a narrow umbilical lip. The umbilical lips are visible on the last few chambers; the earlier ones become obscured by the growth of the prominent central umbo. This species was originally figured by Plummer as *Anomalina grosserugosa*. Jennings gave the new name *A. pinguis*.

Diameter 0.60 to 0.70 mm. Thickness 0.30 to 0.40 mm.

Occurrence.—Jennings recorded this species from the Mt. Laurel and Navesink formations of New Jersey. The species has been reported from the Pecan Gap chalk (Taylor age) and the Corsicana marl of

Texas. Nine reports that it occurs abundantly in the Navesink. It is present in the Redbank at Atlantic Highlands and New Egypt, in the lower New Egypt of the Clementon, Glendola, and Whitesville wells.

ANOMALINOIDES HIGHLANDICUS n. sp.
Pl. 11, figs. 9–11

Test.—nearly planispiral, spiral side slightly evolute, umbilical side involute, biconvex, inner spiral area somewhat depressed, umbilical area distinctly depressed. Equatorial periphery slightly lobulate to plainly lobulate. Axial periphery rounded. *Wall.*—calcareous, smooth, finely perforate. *Chambers.*—7–9 in final whorl, increasing rather rapidly in size, inflated, especially in the adult stages. *Sutures.*—spiral side: limbate, except last few, straight to slightly curved, somewhat depressed. Umbilical side: limbate, except last few, curved, depressed. *Aperture.*—interiomarginal umbilical to extraumbilical; the extraumbilical portion with a thin narrow lip; the umbilical part covered by an umbilical lip. All the umbilical lips of the last whorl are visible and project inward, thus covering the umbilicus. Diameter 0.40 to 0.50 mm. Thickness 0.20 mm.

Remarks.—If the umbilical lips are broken the inner whorls are visible and, the test appears evolute on the umbilical side. The umbilical lips also are visible on the chambers of the inner whorls. This species somewhat resembles *Anomalina tennesseensis* W. Berry in the general shape of the test. It differs from this species in the larger size of the test, lesser degree of evolution on the spiral side, the more limbate sutures, and the finely perforate chamber walls.

Occurrence.—The species is abundant in the Redbank at Atlantic Highland and present in the Redbank at New Egypt. It is present in the lower New Egypt in the Clementon well.

Types.—Holotype (USNM 626475) and paratypes (P 81056 qnd R 5044) from the Sandy Hook member of the Redbank formation, locality NJK-103.

ANOMALINOIDES PSEUDOWELLERI n. sp.
Pl. 12, figs. 1–3

Test.—semi-involute, nearly planispiral, distinctly compressed. Equatorial periphery smooth, circular, slightly lobate near end chambers. Axial periphery rounded. *Wall.*—smooth, distinctly perforate. *Chambers.*—narrow, 12–13 in the last whorl, increasing gradually in size. Last few somewhat inflated. *Sutures.*—thinly limbate, flush with surface throughout majority of test. Slightly depressed between last few chambers. On spiral side gently curved coalescing to form a limbate ring around the spiral suture. Spiral suture depressed. On umbilical side gently curved, coalescing around the umbilicus to form a partial ring of shell material. *Aperture.*—interiomarginal, umbilical-extraumbilical, extending slightly onto the spiral side, with a thin peripheral lip and a distinct umbilical lip. The apertures of the last 4 or 5 chambers open into the umbilicus and are covered by umbilical lips. The previous ones become obscured by the growth of the shell ring. The umbilicus may be open, but usually is occupied by an irregular growth of shell material. Diameter up to 0.55 mm. Thickness 0.20 mm.

Remarks.—This species is similar to *Anomalina welleri* (Plummer). It can be distinguished by the larger size, less limbate sutures, and by the lack of a prominent umbilical plug. It is differentiated from *Anomalinoides acuta* (Plummer) by the less compressed test, the less acute axial periphery, the lack of raised sutures and an elevated central boss on the spiral side.

Occurrence.—This distinctive species is common in the Hornerstown at the Shingle Run and Crosswicks Creek localities.

Types.—Holotype (USNM 626476) and paratypes (P 81057 and R 5045) from the Hornerstown formation, locality NJT-11.

Genus CIBICIDES Montfort, 1808

CIBICIDES HARPERI (Sandidge) Cushman
Pl. 11, figs. 18–23

Anomalina harperi Sandidge, 1932, p. 316, pl. 29, figs. 1,2.

Cibicides harperi Cushman, 1940, p. 38, pl. 7, figs. 3–5; Cushman & Todd, 1943, p. 72, pl. 12, fig. 16; Cushman, 1946, p. 159, pl. 65, figs. 5–7; 1950, p. 10, pl. 4, figs. 33,34.

Remarks.—The Redbank forms differ slightly from the Gulf Coast species. They are somewhat smaller and the spiral side varies from convex to slightly concave. The majority of the species exhibit nearly flat spiral sides. They agree in all other aspects.

Diameter 0.40 to 0.55 mm.

Occurrence.—*Cibicides harperi* was described from the Ripley formation of Alabama and occurs in beds of late Navarroan age in the Gulf Coast. It is common in the Navesink formation of New Jersey. The species is abundant in the Redbank at Atlantic Highlands and is common in the Redbank at New Egypt. It is common in the lower New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotypes R 5142.

CIBICIDES MARYLANDICUS Shifflett
Pl. 12, figs. 4–6

Cibicides marylandicus Shifflett, 1948, p. 74, pl. 5, figs. 4–6.
Cibicides reinholdi Brotzen, 1948, p. 82, pl. 13, figs. 1a–c; Hofker, 1955, p. 10, pl. 1.

Remarks.—The characteristic features of this species are the planoconvex test, the depressed sutures in the adult portion of the test, the smooth walls, and the diagnostic small restricted aperture.

Diameter up to 0.65 mm. Thickness 0.30 mm.

Occurrence.—The species occurs in the Aquia and Vincentown formations, and in the Paleocene of Sweden. It is abundant in the Hornerstown at the Shingle Run and Crosswicks Creek localities. It has been observed in the Clementon well (210′). It also is present in the New Egypt of the Glendola, Whitesville, and Clementon wells.

Types.—Figured hypotype R 5143.

CIBICIDES NEELYI Jennings
Pl. 11, figs. 15–17

Cibicides neelyi Jennings, 1936, p. 39, pl. 5, figs. 4a–c; Shifflett, 1948, p. 75, pl. 5, figs. 7,8.
Cibicides williamsoni Garrett, 1941, p. 156, pl. 26, figs. 15a–c.

Remarks.—The species originally was described from the Hornerstown by Jennings. It is identified by the spiroconvex test, the coarsely perforate walls, and the limbate raised sutures of the initial portion that become simple and depressed in the later portion of the test.

Diameter 0.65 mm. Thickness 0.25 mm.

Occurrence.—The species has been recorded from the Aquia of Maryland. It also occurs in the Salt Mountain limestone and the Nanafalia formation of Alabama. This is a very abundant species in the Hornerstown at Shingle Run and Crosswicks Creek. It has been found in the Glendola well (301–302′) and in the Clementon well (210′).

Types.—Figured hypotype R 5144.

CIBICIDES SIMPLEX Brotzen
Pl. 12, figs. 7–9

Cibicides simplex Brotzen, 1948, p. 83, pl. 13, figs. 4a–c,5a–c.

Remarks.—The Hornerstown forms compare well with material from the Paleocene of Sweden. The distinctive features of this species are flat chambers on the umbilical side, angled axial periphery, the smooth spiral side, and the strongly perforated umbilical side. Brotzen described two types of this species. The Hornerstown species belongs to the first type with flat chambers on the umbilical side.

Diameter 0.30 to 0.50 mm.

Occurrence.—The species occurs throughout the Paleocene of Sweden. It is present in the Shingle Run and Crosswicks Creek localities.

Types.—Figured hypotype R 5145.

CIBICIDES SUCCEDENS Brotzen
Pl. 12, figs. 10–12

Cibicides succedens Brotzen, 1948, p. 80, pl. 12, figs. 1,2, text fig. 21.

Remarks.—The Hornerstown species agrees with the topotype material from Sweden. The species is mainly characterized by a strongly elevated central plug on the spiral side that gives a cone shape to the test. Other diagnostic features are the acute axial periphery which is sometimes keeled, and the curved sutures.

Diameter 0.50 mm.

Occurrence.—The species occurs throughout the Paleocene of Sweden. It is a common species in the Hornerstown at Shingle Run and at Crosswicks Creek. It is present in the Clementon well (210′).

Types.—Figured hypotype R 5146.

CIBICIDES COMPRESSA n. sp.
Pl. 12, figs. 13–15

Gavelinella welleri Hofker, 1955, p. 12, pl. IV.

Test.—small, very low trochospiral, much compressed, with a flattened apertural face. Equatorial periphery smooth, becoming slightly lobate in later portions. Axial periphery rounded. *Wall.*—smooth, finely per-

forate. *Chambers.*—compressed, narrow, not inflated, 9–11 in last whorl, increasing uniformly in size. *Sutures.*—limbate, slightly raised to even with surface, with a tendency in some specimens to become depressed between last few chambers. Rather strongly curved, somewhat obscure in umbonal area on spiral side, because of shell material growth. *Aperture.*—extraumbilical-umbilical with a thin peripheral lip and a distinct umbilical lip. The apertures of 6–7 previous chambers extend into the umbilicus and are covered by umbilical lips. The earlier ones become obscure by growth of shell material. Largest diameter 0.40 mm.

Remarks.—This species differs from *Anomalina welleri* (Plummer) in its somewhat greater size, more compressed test, more strongly curved sutures, and the finely perforate walls. It is distinguished from *Cibicides newmanae* (Plummer) by a greater number of chambers, the limbate sutures, and the rounded axial periphery.

Occurrence.—The species was figured first by Hofker as *Gavelinella welleri* from the Vincentown. It is common in the Hornerstown at Shingle Run and at Crosswicks Creek. It also is present in the Glendola well (301–302′).

Types.—Holotype (USNM 626477) and paratypes (P 81058 and R 5046) from the Hornerstown formation, locality NJT-1.

Genus CIBICIDOIDES Brotzen, 1936
CIBICIDOIDES HILGARDI (Garrett)
Pl. 12, figs. 19–21

Cibicides hilgardi Garrett, 1941, p. 155, pl. 26, figs. 13a–c,14a–b.
Cibicidoides cederstromi McLean, 1951, p. 28, pl. 4, figs. 12–14.

Remarks.—The species is identified by the biconvex test, subacute axial periphery, curved sutures that are depressed in later portion of the test, and the coarsely perforate walls. The Hornerstown species is larger in size but identical in all other aspects. The species is very similar to *Cibicidoides proprius* Brotzen from the Paleocene of Sweden. *C. proprius* has a more conspicuous and larger central plug on the spiral side, and has a somewhat more compressed test.

Diameter 0.70 to 1.0 mm. Thickness 0.50 mm.

Occurrence.—The species was considered a stratigraphic marker by Garrett for the middle Eocene Hatchetigbee and Tallahatta formations of Mississippi and Alabama. It was figured by McLean from the lower Vincentown along Shingle Run. It is a very abundant species in the Hornerstown at the Shingle Run and Crosswicks Creek localities It is also present in the Glendola well (301–302′).

Types.—Figured hypotype R 5147.

CIBICIDOIDES VINCENTOWNENSIS (McLean)

Cibicidoides cederstromi var. *vincentownesis* McLean, 1952, p. 12, pl. 3, figs. 6,9.

Remarks.—The species differs from *Cibicidoides hilgardi* Garrett (= *C. cederstromi* McLean) by the more acute axial periphery, more compressed test, and more finely perforate walls.

Diameter 0.65 mm.

Occurrence.—The species was described from the Vincentown by McLean. It is present in the Hornerstown at the Shingle Run and Crosswicks Creek localities.

Genus PLANULINA d'Orbigny, 1826
PLANULINA CORRECTA (Carsey) Cushman
Pl. 12, figs. 16–18

Discorbis correcta Carsey, 1926, p. 45, pl. 3, fig. 5; Plummer, 1931, p. 188, pl. 14, figs. 1–4.
Planulina correcta Cushman, 1940, p. 36, pl. 6, figs. 11a–c; Cushman & Hedberg, 1941, p. 99, pl. 23, figs. 10a–c; Cushman & Todd, 1943, p. 72, pl. 12, figs. 15a–c; Cushman, 1946, p. 158, pl. 65, fig. 1; 1950, p. 10, pl. 4, figs. 31,32.

Remarks.—Diagnostic characteristics of this species are the much compressed, spiroconvex test, slightly rounded to lobulate equatorial periphery; rounded to subacute axial periphery; smooth finely perforate wall; 5 to 9 chambers of final whorl that rapidly become higher and increase greatly in size in adult stages; curved sutures that are strongly limbate, somewhat raised in earlier portion, not limbate, slightly depressed in later portion. The aperture is interiomarginal-umbilical with a thin peripheral lip and an umbilical lip. The umbilical lips of the preceeding chamber project into the umbilicus.

Diameter 0.40 to 0.50 mm. Thickness 0.10 mm.

Occurrence.—This species is found in the Upper Navarro of the Gulf Coast. It is

present in the Navesink formation and in the Redbank formation at New Egypt. In the Redbank at Atlantic Highlands it is abundant. It is present in the lower New Egypt in the Clementon, Glendola, and Whitesville wells.

Types.—Figured hypotype R 5148.

PLANULINA MULTIPUNCTATA Bandy
Pl. 12, figs. 22–24

Planulina multipunctata Bandy, 1951, p. 506, pl. 74, figs. 9a–c.

Remarks.—The Redbank forms are identical with the California species. They are identified by the spiroconvex test with umbonal masses on both sides; the equatorial periphery which becomes slightly lobulate in the adult stages; the abruptly rounded to subacute axial periphery; 8–10 chambers of final whorl that increase rather rapidly in size, slightly inflated in later portions; narrowly limbate sutures, slightly depressed in later portion; and the smooth punctate wall. An examination of the California and Redbank species shows the aperture to be interiomarginal-umbilical to extraumbilical with a thin peripheral lip and an umbilical lip. The umbilical lips of the previous chambers surround the umbilical umbonal mass.

Largest diameter up to 0.70 mm.

Occurrence.—The species is present in the Redbank at Atlantic Highlands.

Types.—Figured hypotype R 5149.

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RUGOSE CORALS FROM REEF LIMESTONES IN THE LOWER DEVONIAN OF NEW YORK[1]

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ABSTRACT—A new rugose coral fauna from a previously undescribed reef facies of the Coeymans limestone of early Early Devonian age in New York consists of 9 species, all new, assigned to 6 genera, 3 new. Collections are from 9 separate reefs or reef areas in which individual reef-knobs average 100 feet in diameter and 20 feet in height. The fauna is peculiar in that most of the species are characterized by partial or complete stereoplasmic filling of the corallum. In this respect it finds a close analogue in the Koneprus limestone of Bohemia (also a reef facies) but the genera in the two faunas are not closely related. Two of the species seem to be early representatives of characteristic later genera of Onondaga age, but the phylogenetic relationships of the other species are not clear.

Individual variation in eight of the described species is expressed in standard statistical terms and illustrated by means of scatter diagrams, frequency curves and average valve curves. In the species studied the septal ratio (number of major septa/diameter) decreases with increasing diameter both among adults and in ontogeny. The tabularium ratio (tabularium diameter/diameter) is constant with increasing diameter among adults but ontogenetically shows a marked decrease with increasing diameter. Variation within colonies of *Tryplasma fascicularium* is of the same magnitude as variation within populations of solitary cylindrical corals but the conical species show much greater variation.

INTRODUCTION

RUGOSE coral faunas of Helderberg (early Early Devonian) age in North America have been little studied, partly because of the limited geographic extent of rocks of this age. The corals described here are from a coral-stromatoporoid reef facies of the Coeymans limestone not previously discussed in literature. Nine new species are described, all clearly separable from previously described species in spite of the inadequacies of previous work on corals of this age. The new species and genera are most closely related to younger corals from the Onondaga and equivalent formations, but the fauna as a whole has no close analogue in North America. The following corals are described:

Siphonophrentis variabilis n. sp.
Briantelasma americanum n. gen., n. sp.
B. knoxboroense n. sp.
Pseudoblothrophyllum helderbergium n. gen., n. sp.
P. arrectum n. sp.
P. munnsvillium n. sp.
Fletcherina incognita n. sp.
Tryplasma fascicularium n. sp.
Aknisophyllum consuitum n. gen., n. sp.

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Reef deposits are common in Silurian and Devonian rocks as well as in rocks of other ages, but reports of lower Lower Devonian (Gedinnian) reefs are sparse and no descriptions of reef corals of this age are known to the author. Hill (1957) in a review of Devonian coral faunas cites only 2 examples of possible Gedinnian reefs. Probable Gedinnian (possibly Upper Silurian) reef corals are mentioned from North Queensland, Australia (Hill, 1957, p. 46). In addition reefs of this age are cited by Hill (op. cit., p. 47) from eastern North America on the authority of Freeman (1951). The latter author in discussing the well known reefs of Niagara age in the Illinois basin area states "the reefs continued to grow probably during the Early Devonian." (Freeman, 1951, p. 26.) Freeman gives no direct evidence to support her contention and it seems very unlikely that the reef growth extended into either latest Silurian or Early Devonian time (see Lowenstam, 1950, 1957, and his references to earlier work on reefs of Niagara age).

Non-reef coral faunas of Gedinnian age are better known, but by and large this seems to have been a time of limited variety and geographic extent for the corals (Hill, 1957, p. 42, et seq.). In North America only

the following 9 rugose coral species have previously been described from rocks of Helderberg (or possibly Helderberg) age.

New Scotland limestone, New York

1. *Zaphrentis roemeri* Milne Edwards and Haime, 1851
2. *Enterolasma strictum* (Hall), 1874
3. *Cyathophyllum patella* Quenstedt, 1880 (probably New Scotland limestone).
4. *Duncanella rudis* Girty, 1895.

Linden group, Tennessee

5. *Zaphrentis desori* M.-E. and H., 1851.

Helderberg formation (as used by Swartz 1913), Maryland (includes Keyser limestone)

6. *Cyathophyllum oherni* Swartz, 1913
7. *Cystiphyllum fasciculatum* Swartz, 1913
8. *Streptelasma cumberlandicum* Swartz, 1913
9. *Heliophyllum* cf. *H. corniculum* Lesueur, Swartz, 1913

All of these were originally poorly described and inadequately illustrated by modern standards but all are markedly different from any of the reef species herein described.

In addition to those corals originally described from rocks of Helderberg age, several workers have listed the New York species from rocks of this age in Maryland and several midwestern states. But even if all listings are assumed to be correct, the sum total of our knowledge of North American rugose corals of Helderberg age is very small.

ACKNOWLEDGMENTS

The writer is indebted to Dr. L. V. Rickard, now Senior Paleontologist, New York State Geological Survey for numerous discussions of problems concerning the age and stratigraphy of the bioherms in the Coeymans limestone. Information gained independently (including the discovery of some of the reefs) was freely given and rugose corals collected by Rickard were sent to the author for inclusion in the present study. A detailed discussion of Helderberg stratigraphy, including that of the reefs, will be published by Rickard.

Laboratory work previous to July, 1957 would not have been possible without a Project Grant of the Geological Society of America which covered all of the expenses of thin-sections and photographic work to that time. Field work in the summers of 1951–1956 was part of a larger program supported by the New York State Geological Survey. Appreciation is expressed to Henry R. Aldrich of the Society and to John G. Broughton, New York State Geologist, for their aid.

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The manuscript was critically read by Jean Berdan, U. S. Geological Survey and R. S. Boardman, U. S. National Museum and many of their suggestions have been incorporated into the final draft. Textfigures 2 to 33 were drafted by Mrs. Mary Wagner; photographs of coral exteriors are by N. W. Shupe; most of the thin-sections were prepared by William C. Pinckney, and photographed by the author. The contributions of all these individuals are gratefully acknowledged .

AGE AND STRATIGRAPHIC RELATIONSHIPS

The Coeymans limestone is the oldest formation in the Helderberg group in eastern New York. West of the Albany area higher formations of the Helderberg group (New Scotland and Becraft limestones) and the Oriskany group are cut out one by one by pre-Onondaga erosion until in the area between Oriskany Falls and Manlius the Coeymans limestone is overlain directly by the Onondaga limestone, except where local patches of Oriskany sandstone intervene. At several places within the Oriskany Falls-Manlius area a bioherm or reef facies is developed within the Coeymans limestone. This facies has apparently not previously been noted in print.

A total of nine reefs or reef areas have been found. The larger reefs are expressed topographically by a series of knobs which have an average height of 20 feet and an average diameter of 100 feet. The distribution pattern of the knobs is apparently dependent on the accidents of exposure and no good idea of original shape or distribution can be attained. The smaller reefs are composed of single small knobs but may be remnants of more extensive areas of reef development. It is possible that the original form of the reefs was destroyed during

Devonian time by pre-Oriskany or pre-Onondaga erosion. It seems likely that the reefs of the Helderberg group were formed as small patch reefs on a stable shelf as they are similar in most respects to other described Paleozoic reefs of this type.

The reef facies of the Coeymans is characterized by greater or lesser concentrations of coral in a matrix of coarse-grained, light-colored, crinoidal limestone. In places, only widely scattered corals are present and the reef rock is composed almost entirely of crinoidal debris. Normal bedding is lacking, although haphazardly arranged, irregular partings are present. Stromatoporoids and tabulate corals generally abound, but often in different parts of a reef and either may be uncommon on the smaller reefs. Rugose corals are abundant or widely scattered in different parts of the various reefs. Brachiopods and other invertebrates are only locally common.

The described corals do not by themselves indicate the exact age of the rocks from which they were collected although they strongly suggest Early Devonian age. *Siphonophrentis* is known from rocks of Onondaga (late Early Devonian or early Middle Devonian) and Hamilton (Middle Devonian) age. *S. variabilis* of Helderberg age displays primitive characters which suggest that it may be ancestral to previously described younger species of *Siphonophrentis*. Similarly *Pseudoblothrophyllum helderbergium* of Helderberg age may be a precursor of the Onondaga and Hamilton species of *Blothrophyllum*. Therefore both *S. variabilis* and *P. helderbergium* suggest pre-Onondaga age. *Fletcherina* has previously been described from the Givetian (upper Middle Devonian) of Australia and the Devonian of China. It is suggestive of Devonian age but previous data is sparse. *Tryplasma* is a common Silurian form but ranges into the Lower Devonian. Other genera and species described are new and their relationships and age significance are not known.

The associated brachiopods have not been studied but appear to be of the common species found in the Coeymans limestone in New York. A few ostracods from the south end of the Orchard reef were collected and studied by Jean Berdan. They are of pre-Oriskany age (Berdan, oral communication, 1958).

The faunas of the various reefs are very similar, and differences may be due to slight age differences or to geographic separation of the reefs.

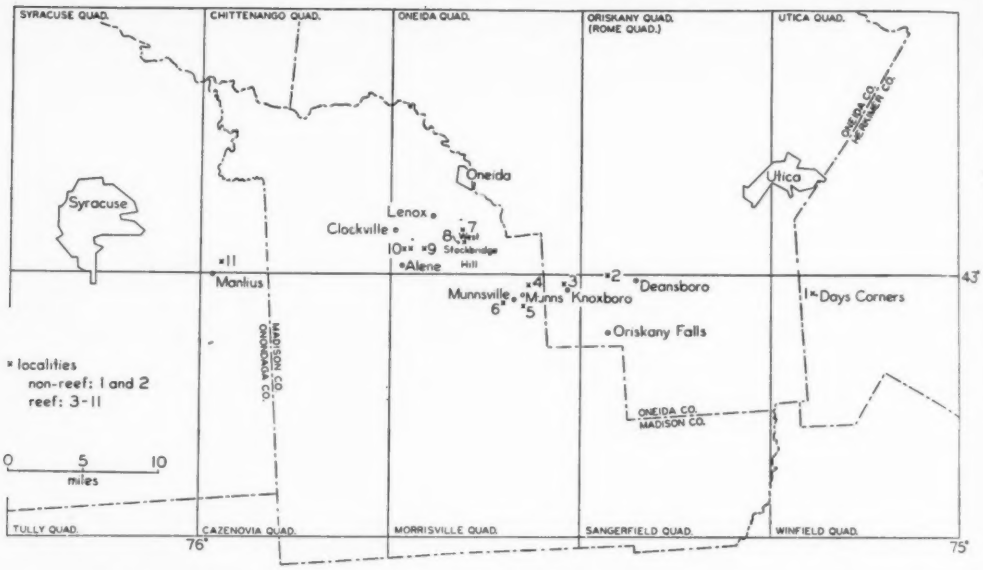
The physical relationships of the rocks give the clearest indication of age. The reef facies deposits overlie normal Coeymans limestone wherever the basal contact is seen. At one time the reefs were overlain by Oriskany sandstone, as coarse sandstone dikes, lithologically identical to the Oriskany sandstone are present in the upper few feet of the Mosquito Point reef (locality 4, text-fig. 1). The Oriskany sandstone in New York was laid down as a blanket deposit following deposition of the Helderberg group. At this time or during subsequent pre-Onondaga erosion some of the sand was apparently drifted into cracks in the upper part of the reef facies limestone. Similar dikes of Oriskany sand were found in the upper part of the non-reef Coeymans at locality 2 (text-fig. 1) in the northwest corner of the Oriskany Falls 7½ minute quadrangle. The normal Coeymans thins under the reefs and there is little question that the reefs are a facies of the Coeymans limestone.

The Coeymans limestone is of Helderberg age (early Early Devonian) in the standard New York section, and is correlated with the Gedinnian of Europe by Cooper et al. (1942).

MORPHOLOGY AND STRUCTURE

Terminology.—Terminology for rugose coral description is sufficiently standardized so that few definitions or explanations are required. An excellent general discussion and glossary is to be found in the Treatise on Invertebrate Paleontology (Hill, 1956, p. 234–251). However, certain general peculiarities of the present fauna are such that much space can be saved in the section on systematic descriptions by assigning a specific meaning, for present purposes, to certain ordinary words which would otherwise require elaboration wherever used.

Tabulae and dissepiments collectively can be referred to as *horizontal* skeletal elements or tissue in contrast to the septa which are *vertical* elements (Hill, 1935, p.



TEXT-FIG. *1*—Index map of central New York showing location of reef and non-reef collecting localities. Reefs 3–6 compose the eastern reef group; reefs 7–10 the central group; and reef 11 is the western group.

498, 508). In transverse sections of many of the species here described, the septa are sharply set off from other deposits of stereoplasm which fill in the surrounding empty spaces. Such other deposits will be referred to as *interseptal* if they occur in the spaces between laterally adjacent septa, and *axial* if they occur in an axial zone to which the major septa do not extend.

Because of the prevalence of excess stereoplasmic deposits in the species being considered it is convenient to refer to *open* and *closed* tabularia. The former term will refer to tabularia which are occupied only by relatively thin tabulae and septa, the latter to tabularia that are virtually filled with stereoplasm.

The term *marginarium* will be used to refer specifically to a relatively thick peripheral zone outside of the tabularium, to which minor septa are more or less limited and which is entirely filled with stereoplasm. The term is more broadly defined in the Treatise (Hill, 1956, p. 248).

Microstructure.—The microstructure of the various Coeymans limestone species with wide marginaria (*Pseudoblothrophyllum Briantelasma*, and *Siphonophrentis* spp.), is sufficiently uniform to warrant a general description. Individual differences will be described in the systematic section. In most of the material the septal structure is moderately well preserved although some silification and recrystallization of calcite is evident in most thin-sections. The septa are similar to the monacanthine type described by Hill (1936, p. 197, 213–214; 1956, p. 234–236).

In transverse section under crossed nicols the septa appear to have a dark, irregular, discontinuous center line which represents the axes of the trabeculae. These are in the axial plane of the septa and are cut at varying angles to the plane of the section. On either side of the septal axis in most sections the tissue appears featureless. In other individuals however, this tissue is composed of fibers arranged pinnately relative to the septal axis. Septal boundaries are generally clearly defined in the tabularium and in most of the marginarium but are generally obscure in peripheral areas.

The septa are either attenuate or dilated to a greater or lesser extent. In the marginarium the septa are commonly separated by lamellar stereoplasm, but may be in lateral contact in some parts of some individuals. The septa are generally sharply

bounded but in some cases the lamellar interseptal stereoplasm merges imperceptibly into the stereoplasm of the septa. In each interseptal space the laminae are divided by a thin, irregular center line, the significance of which is not clear. On either side of this line the laminae appear as short curved lines, concave toward the center line and the axis of the coral. In transverse section the interseptal and axial deposits of "closed" tabularia are identical to and continuous with the interseptal deposits of the marginaria.

Longitudinal sections show varying structure depending in part on which tissue was intersected. Sections through and parallel to septa tend to show the trabecular axes as dark, irregular lines directed up and in (toward the calice). In most sections the trabeculae are uniformly interrupted along lines slanting up and out, approximately at right angles to the trabeculae; these seem to be analogous to growth lines, the interruptions representing a resting stage separating earlier and later growing stages.

Interseptal longitudinal sections show only indistinct, alternatively dark and light bands that trend up and out with slight upward convexity; these are parallel to, and probably of the same origin as the septal "growth lines" mentioned above.

The stereoplasmic filling of the marginarium is partly due to septal dilation but mostly to deposition of lamellar stereoplasm. The latter must be considered horizontal tissue (cf. Hill, 1934, p. 76–77), and is analogous to dissepiments in form, structure and presumed manner of deposition by the polyp. It is not known whether the deposits should be considered to represent suppressed or incipient dissepiments, but corals of this type should be separated from those in which the stereoplasmic filling is due entirely to septal dilation.

In partially filled tabularia it is rather clear that filling is mainly due to dilation of the tabulae. In longitudinal section the base of each tabula is marked by a fine, dark, straight or smoothly curved line which seems to represent the initial deposit of the polyp after pulling away from the next lower surface. This is in contrast to the top of the tabula which is more irregular and has no such obvious boundary. In completely filled tabularia individual tabulae cannot be distinguished, but the source of the filling is presumably analogous. With continuous upward deposition of horizontal tissue there would be no tabula bases and in reality no tabulae. Part of the tabularium is occupied by the septa and septal dilation undoubtedly plays a part in filling the tabularium, but most of the filling seems to originate as horizontal tissue.

The filling of the interseptal and axial parts of the coralla by horizontal tissue is a significant characteristic of the corals here described, and serves to separate them from superficially similar corals (*Pycnactis*, *Kodonophyllum*, the chonophyllids etc.) in which the marginarium is formed by septal dilation.

ANALOGOUS FAUNAS AND ECOLOGY

The nearest analogue of the described fauna, although not composed of closely related species, is found in the Koneprus limestone in Bohemia. The Koneprus is distinctly a reef facies and the rugose corals display considerable deposits of stereoplasm.

The corals from the Koneprus were most extensively described by Počta (1902, see plates 29–34, 47–67, 103, 109, and 115). According to data in Chlupáč (1955, p. 160, 206) the corals are mostly from bioherms which are, however, primarily composed of stromatolites. The Koneprus is generally considered to be of somewhat younger Early Devonian age (Coblentzian; Chlupáč, 1955, p. 217; Svoboda and Prantl, 1949, p. 87) than the Helderberg of New York.

The stereoplasm-rich solitary rugose corals of the Koneprus and Helderberg are primarily from well developed reef facies and it seems likely that the extra stereoplasm served to strengthen the coral skeleton and make them more wave resistant. In other Paleozoic reefs stereoplasmic filling did not necessarily take place. The rugose corals may have adapted to rigorous conditions in other ways (i.e. by building colonies) or the reefs may have been in somewhat deeper and quieter water.

Stereoplasm filled corals are known from non-reef environments also. The widely noted rugose fauna from the Silurian of the Island of Gotland, Sweden, includes many genera and species characterized by stereoplasmic filling (see Wedekind, 1927). According to Hadding (1941, p. 28–33) the

solitary corals are found primarily in the inter-reef shales although Twenhofel (1950, p. 193) and Jux (1957, see review by Hessland, 1958) indicate that at least some of the filled corals are found in or closely associated with the reefs. Wedekind and Tripp (1930, p. 302,304) list *Chonophyllum* and *Dinophyllum* from the shales but indicate that *Kodonophyllum* is a reef form. Species of all 3 genera show excess stereoplasmic deposits (Wedekind, 1927).

Contrasting environmental interpretations of skeletal strengthening have previously been made. Butler (1937, p. 91–93) noted that specimens of *Omphyma* from the Wenlock limestone near Dudley, England, had undilated, discontinuous septa while those from the Wenlock shale had continuous, dilated septa. He suggested that the excess stereoplasm in the shale form was due to the "depressing effect of the environment"; slow upward growth, with no shortage of $CaCO_3$, resulted in thickened skeletal elements. Jeffords (1948, p. 44) made similar observations on lophophyllidid corals from Pennsylvanian and Permian rocks of Kansas.

In contrast, Rozkowska (1957, p. 129–130) noted that of three subspecies of *Macgeea bathycalyx* from Middle Givetian rocks of Poland, the one with the thinnest, most delicate structure was from the shales, and the stronger ones were from limestones. She suggested that the former developed in quieter and deeper water while the latter were in shallow, agitated water. Both Rozkowska and Butler interpreted the environmental adaptation in terms of evolution and not individual variation.

Although the function of the stereoplasmic filling of corals has undoubtedly varied, it seems likely to be an adaptation to environment. It is obviously not a simple relationship however, and more detailed biological and physical data are needed for above mentioned and other occurrences before a more complete explanation can be attained.

INDIVIDUAL VARIATION IN DESCRIBED SPECIES

An important part of the systematic description of any species should ideally be an indication of the extent and nature of individual variation within the species, and of variation between populations of the species. This ideal is seldom met because of difficulty in getting adequate samples and in recognizing fossil populations. The reef fauna of the Coeymans, however, is excellent for such a study. Individual rugose corals are abundant, but only 4 species are common. The reefs are small enough so that individuals of each species collected from each reef can be considered to represent local populations, and some comparison of these populations is possible. Over 100 individuals of each of the common species are utilized in the present study, and smaller numbers of less common species are analyzed and compared to the common ones.

Biometrics in the present study are used primarily to express and analyze variation, and only incidentally to discriminate species or populations. Methods used are for the most part summarized in Mayr, Linsley and Usinger (1953, p. 125–154) but reference to Simpson and Roe (1939) was necessary to clarify a few points.

The following characters have been quantitatively treated in the present study. All measurements are in millimeters (to nearest mm) unless otherwise stated.

Diameter (d). Measured in transverse section by averaging greatest diameter and diameter measured at right angles to same. Occasional measurements were made in longitudinal sections. For analysis of individual variation, diameter was measured in section at or just below the base of the calice, or in highest examined section of cylindrical forms. For analysis of variation in ontogeny, measurements were made in serial sections.

Tabularium diameter (d^t). Average of 2 measurements made along same lines and in same section as corresponding diameter.

Width of marginarium. Equals $\frac{1}{2}(d-d^t)$, or can be calculated from tabularium ratio below. Not directly used in present work.

Length. Total length of solitary coral from apex to rim of calice measured along convex side. This factor is not analyzed here for two reasons: 1) the apex is missing in many specimens which are adequate for measurement of other characters, and 2) 3 of the 4 common species are characteristically cylindrical with growth variation in septal and

tabularium ratio essentially limited to initial conical portion. Observed range in centimeters is given in systematic descriptions.

Number of major septa (n). Direct count in transverse section in which corresponding diameter was measured.

The following 2 ratios facilitate the analysis of the above characters.

Septal ratio (n/d). Number of major septa per 1 mm diameter (septal coefficient of Voynovskiy-Kriger, 1954; see Chilingar, 1956, p. 406).

Tabularium ratio (d^t/d). Tabularium diameter as fraction of total diameter.

The following standard terms are used in the present study. Analysis was by class groups rather than individuals in the larger collections.

Mean (M.). Arithmetical average of any character or ratio.

Standard deviation (S.D.). Measure of variation from sample mean in units of character being analyzed.

Coefficient of variation (C.V.). Expresses S.D. as percentage of mean; dimensionless number more directly comparable to similar figure representing unrelated characters.

Standard error of mean ($S.E._M$). Measure of closeness of sample mean to population mean.

Observed range (O.R.). Minimum and maximum values of given character in given sample.

Sample size (N.). Number of specimens in which values of given character have been measured.

Size.—Size variation is to be expected in any species and can be a result of ontogeny, ecology and random genetic differences. In corals all three play a part and as a result size is often not considered important. There are limits to size variation however and a knowledge of the various aspects of size is important for a full understanding of individual variation and characterization of species. Size statistics for each species are given in tables 2–6. It should be noted that the coefficients of variation of the analyzed ratios exceed or are the same as the size (diameter) coefficient of variation in some cases.

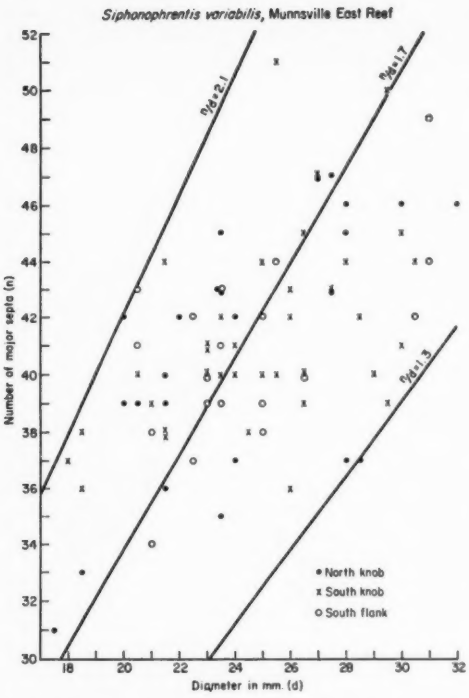
In cylindrical species (*Siphonophrentis variabilis*, *Pseudoblothrophyllum helderbergium*, and *Tryplasma fasciculariu*m) measurements are based on sections through the cylindrical portions of the coralla and the importance of ontogeny as a factor is greatly reduced. In these species diameter variation is presumably due to ecological factors plus random genetic differences. In conical species such as *Briantelasma americanum* there are no firm criteria for eliminating juveniles and ontogeny may be a more important factor in the statistics. However, much juvenile data was eliminated by excluding from quantitative consideration obviously undersize individuals and by making all measurements in a transverse section just below the base of the calice.

Length is perhaps controlled more by external factors than is diameter, since length must often be largely a function of life span. Length, however is not statistically treated in the present study because of the difficulty in obtaining and interpreting adequate data.

Number of septa.—A significance to number of septa has long been recognized and many taxonomic works give septal counts and occasional information on variation in this character. It is general knowledge, however, that number of septa is to a large extent a function of size. But septal ratio (number of septa/diameter) also varies with size as shown by Voynovskiy-Kriger (1954, see Chilingar, 1956, p. 406), who considered that plotting ontogenetic changes in diameter against number of septa was the most effective way of utilizing this value. The most recent analysis of septal ratios is by Rozkowska (1957).

In the present work, septal number data are graphically presented in 3 ways (in each case the septal number (n) is the number of major septa): 1) Scatter diagrams plotting septal number against diameter, 2) septal ratio frequency curves, and 3) curves of average septal ratio variation with diameter.

The scatter diagrams (text-figs. 2–12) are a direct and easily visualized expression of individual variation in number of major septa and diameter. Each point on the figures (except as noted) represents a presumably mature individual. The straight lines represent mean, maximum, and minimum valves of the septal ratio for the collection plotted and should not be confused with other types of regression lines which



TEXT-FIG. 2—*Siphonophrentis variabilis*. Scatter diagram of number of major septa×diameter in 79 specimens from the Munnsville East reef. Straight lines represent plots of mean, minimum, and maximum values of septal ratio for collection.

are not drawn. The diagrams show directly the overall variation in diameter, and the variation in septal number for a given diameter, as well as the general increase in septal number with diameter.

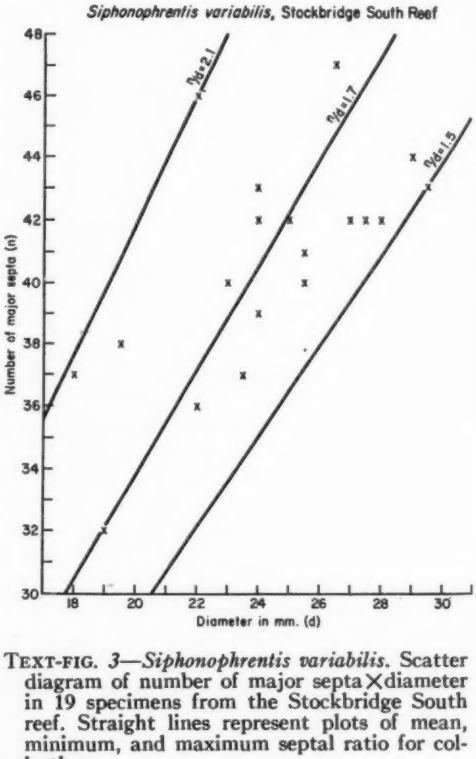
The septal ratio frequency curves (text-figs. 13–16) show that septal ratio has an approximately normal distribution in the 4 common species. The distribution is somewhat erratic in small samples of *B. americanum* and *T. fascicularium* although approximately normal in larger samples of the same species. Both species will be more fully discussed in later sections.

The average septal ratio curves (text-figs. 17–20) summarize the adult variation in septal ratio with diameter in the 4 common species. In each species there is a decrease in mean septal ratio with increasing diameter, indicating that the septal number does not increase in proportion to diameter.

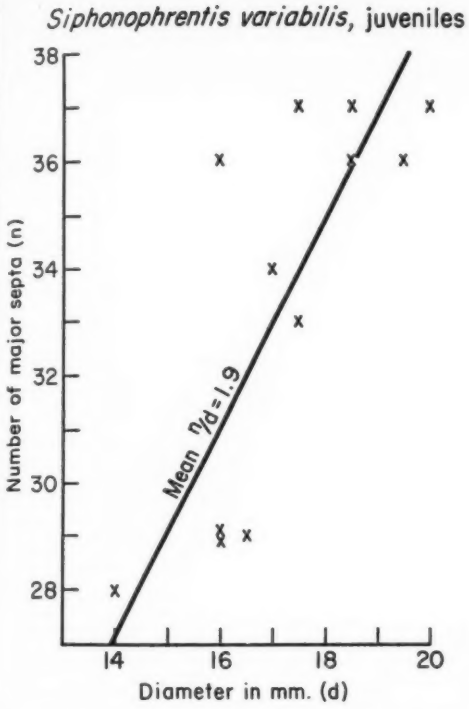
The same relationship between septal ratio and diameter can be seen in the scatter diagrams if carefully studied (especially text-fig. 5). The general trend of the plotted points is across the lines representing the mean, from the maximum ratio at low diameters to the minimum ratio at high diameters.

An ontogenetic decrease in septal ratio has been noted by Voynovskiy-Kriger (1954, figs. II) and is to be expected from the above data. Serial sections of individuals of the species under discussion inevitably show a sharp decrease in septal ratio in conical parts of coralla and a slight decrease or irregular variation in cylindrical parts.

The septal ratio trend among adults is most striking in *B. americanum* (text-figs. 5, 6, and 18). This should perhaps be expected from the fact that most individuals of this species are conical in shape, the conical stage being the stage of greatest change. Data for the other common species (text-



TEXT-FIG. 3—*Siphonophrentis variabilis*. Scatter diagram of number of major septa×diameter in 19 specimens from the Stockbridge South reef. Straight lines represent plots of mean, minimum, and maximum septal ratio for collection.



TEXT-FIG. 4—*Siphonophrentis variabilis*. Scatter diagram of number of major septa×diameter in 12 immature specimens from various localities. The straight line represents the mean septal ratio for the group.

figs. 17, 19 and 20) are derived from cylindrical stages, and septal ratio decrease with diameter is less marked. This difference is shown also by the septal ratio coefficients of variability which are high in conical species such as *B. americanum* and *B. knoxboroense*, and much lower in the cylindrical species.

In the cylindrical forms, including *T. fasciculariu*m, ontogenetic variation is significantly reduced in importance by sampling only the cylindrical stages and not considering conical juveniles. No such clear criteria for recognizing juveniles exists in the conical *B. americana* and some additional variation is perhaps due to inclusion of a few immature individuals. On the other hand, it is possible that greater variation is inherent in conical growth and that conical mature individuals will as a general rule show greater variability.

Septal ratio statistics for all species are given in tables 1–6. Coefficients of variation are constant in different populations of each of the common species but vary considerably from colony to colony of *T. fasciculariu*m and between different species.

Rozkowska (1957) recently made de-

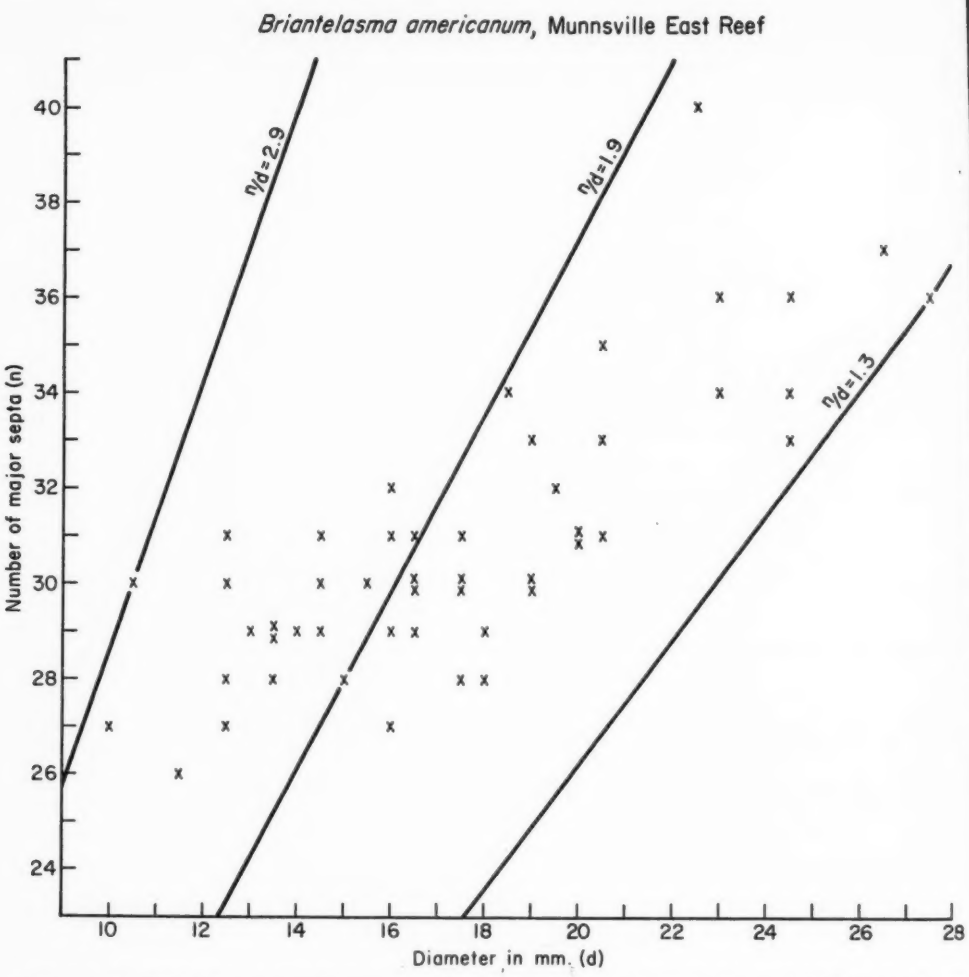
TABLE 1—*Siphonophrentis variabilis*

	Munnsville E. Reef	Stockbridge S. Reef	Total*
Diameter:			
N.	79	19	130
M.	24.6	24.3	24.7
O.R.	17–32	18–30	17–37
S.D.	3.5	3.3	3.8
C.V.	14.3	13.4	15.2
S.E.$_M$	.40	.75	.33
n/d:			
N.	79	19	128
M.	1.7	1.7	1.7
O.R.	1.3–2.1	1.5–2.1	1.3–2.1
S.D.	.2	.2	.2
C.V.	11.9	9.8	12.1
S.E.$_M$	.02	.04	.02
d'/d:			
N.	79	19	130
M.	.77	.75	.77
O.R.	.63–.89	.60–.85	.60–.92
S.D.	.06	.07	.06
C.V.	7.7	9.5	8.4
S.E.$_M$	.007	.016	.006

* Includes material from localities in addition to those detailed.

TABLE 2—*Briantelasma americanum*

	Munnsville E. Reef	Mosquito Pt. Reef	Knoxboro Reef	Total
Diameter:				
N.	62	41	15	118
M.	17.6	20.3	18.4	18.6
O.R.	9–28	10–30	11–25	9–30
S.D.	4.4	5.3	3.8	4.9
C.V.	25.2	26.1	20.8	26.2
S.E.$_M$	.56	.83	.99	.45
n/d:				
N.	49	31	13	93
M.	1.9	1.7	1.8	1.8
O.R.	1.3–2.9	1.1–2.4	1.5–2.6	1.1–2.9
S.D.	.4	.3	.3	.4
C.V.	19.4	20.9	18.6	20.6
S.E.$_M$	.05	.06	.09	.04
d'/d:				
N.	58	41	14	113
M.	.48	.47	.52	.48
O.R.	.32–.60	.33–.62	.41–.59	.32–.62
S.D.	.07	.07	.05	.07
C.V.	15.4	15.5	9.5	15.0
S.E.$_M$	.009	.011	.013	.007



TEXT-FIG. 5—*Briantelasma americanum*. Scatter diagram of number of major septa×diameter in 49 specimens from the Munnsville East reef. Straight lines represent plots of means, minimum, and maximum septal ratio for collection.

tailed septal ratio analyses of several corals of Middle and Late Devonian age from Poland. She showed number of major septa for each specimen in diameter classes by means of tables (effectively scatter diagrams). For each diameter class she determined the median septal number class and used the class values of septal number and diameter to arrive at a septal ratio (her Mc) representative of each diameter class (Rozkowska, 1957, p. 84–85). The mean value of Mc for each species (her Ms) was used as representative of the species in comparison with other species. Rozkowska used graphs of the median septal number per diameter class and septal ratio frequency curves to further illustrate her data.

The general usefulness of Rozkowska's analyses is shown by the evolutionary trends in septal ratio (expressed as Ms) that she demonstrated in Middle and Upper Devonian species of *Thamnophyllum* and *Macgeea* (Rozkowska, 1957, figs. 3 and 11, tables 6 and 8).

Rozkowska's "Ms" value is not the mean septal ratio as used in the present paper,

TABLE 3—*Briantelasma* and *Pseudoblothrophyllum* spp.

	B. knoxboroense	*P. munnsvillium*	*P. arrectum*
Diameter:			
N.	10	22	8
M.	17.7	25.4	20.1
O.R.	12–31	21–31	17–24
S.D.	5.6	2.7	2.7
C.V.	31.6	10.5	13.2
S.E.M	1.77	.57	.94
n/d:			
N.	6	21	5
M.	2.0	1.6	1.7
O.R.	1.5–2.6	1.3–1.8	1.5–1.8
S.D.	.4	.1	.1
C.V.	18.3	8.8	6.7
S.E.M	.15	.03	.05
d^t/d:			
N.	10	21	8
M.	.68	.66	.53
O.R.	.62–.74	.55–.76	.43–.63
S.D.	.03	.06	.07
C.V.	5.1	8.6	13.2
S.E.M	.011	.012	.025

TABLE 4—*Pseudoblothrophyllum helderbergium*

	Stockbridge N. Reef	Stockbridge S. Reef	Alene E. Reef	Total*
Diameter:				
N.	53	19	11	107
M.	36.1	37.6	38.5	36.4
O.R.	28–47	31–43	29–51	27–51
S.D.	4.2	2.9	5.4	4.9
C.V.	11.6	7.8	14.1	13.4
S.E.M	.57	.67	1.64	.48
n/d:				
N.	49	19	10	101
M.	1.3	1.3	1.3	1.3
O.R.	1.0–1.5	1.1–1.4	1.1–1.4	1.0–1.6
S.D.	.1	.1	.1	.1
C.V.	10.5	8.5	9.9	10.5
S.E.M	.02	.02	.04	.01
d^t/d:				
N.	53	19	11	107
M.	.56	.57	.59	.57
O.R.	.45–.73	.46–.68	.49–.74	.41–.74
S.D.	.07	.07	.06	.07
C.V.	12.2	11.7	10.9	12.0
S.E.M	.009	.015	.020	.007

* Includes material from localities in addition to those detailed.

but it approaches it very closely (Ms values of *S. variabilis* and *P. helderbergium* are 1.7 and 1.4 respectively). The statistical mean and allied values are here preferred as they are determined by standardized procedures.

Most of Rozkowska's analyses are of species, but 2 populations of *Thamnophyllum kozlowskii* are compared (Rozkowska, 1957, p. 85–88) with results similar to those obtained from the Helderberg species which are under discussion. In her analyses of populations and/or species of the colonial *Thamnophyllum*, Rozkowska does not differentiate between inter- and intra-colony variation. The present study of *Tryplasma fascicularium* suggests that such differentiation many produce interesting results.

TABLE 5—*Tryplasma fascicularia*

	Knoxboro Reef	Munnsville East Reef	Mosquito Point Reef				Stockbridge S. Reef	Alene W. Reef	Total by colonies
	Colony No.								
	1	2	3	4	5	6	7	8	
Diameter:									
N.	19	6	50	30	9	7	27	9	8
M.	4.6	4.8	5.5	4.4	3.9	4.8	4.7	4.6	4.65
O.R.	3.5–6.0	3.5–5.5	3.7–8.0	2.7–6.5	3.0–5.0	4.0–5.7	3.5–6.0	4.0–5.0	3.9–5.5
S.D.	.6	.8	.9	.8	.6	.6	.5	.4	.4
C.V.	13.7	16.3	15.9	17.9	14.5	12.7	11.5	8.1	9.3
S.E.M	.15	.32	.12	.14	.19	.23	.10	.12	.15
n/d:									
N.	19	6	50	30	9	7	27	9	8
M.	4.4	4.6	4.5	5.1	5.7	4.5	4.3	4.6	4.7
O.R.	3.8–5.1	4.2–5.7	3.8–5.6	4.0–6.9	4.9–6.9	4.0–4.8	3.6–4.8	4.4–5.5	4.3–5.7
S.D.	.4	.6	.5	.6	.6	.3	.3	.4	.46
C.V.	7.9	12.9	10.4	11.6	11.1	6.4	6.7	7.6	9.8
S.E.M	.08	.24	.07	.11	.21	.11	.05	.12	.164

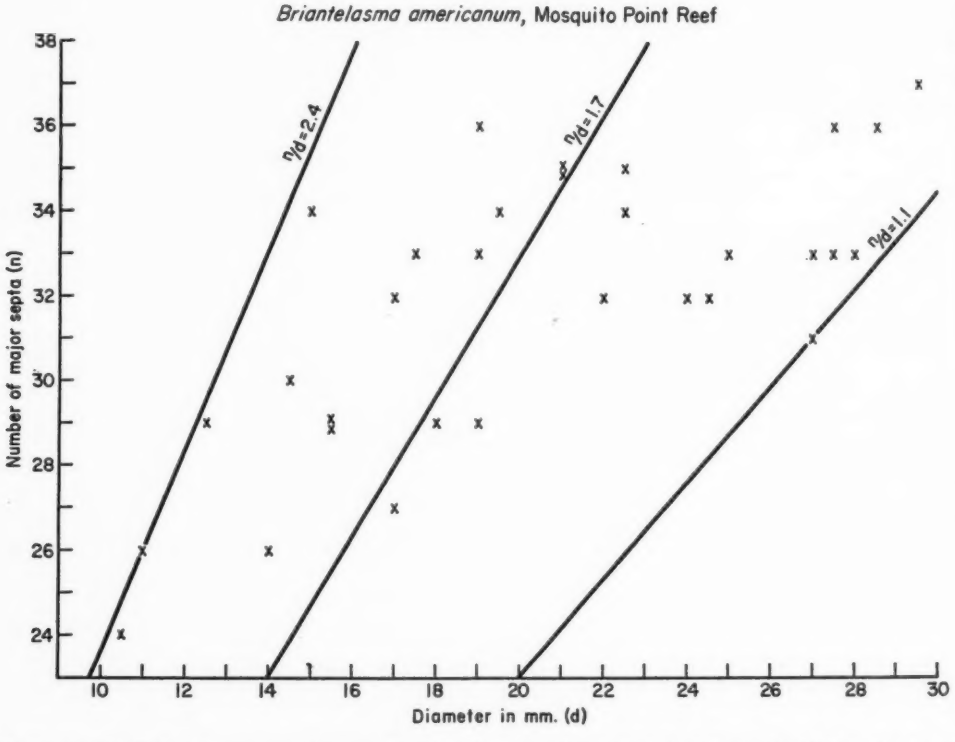
TABLE 6—*Aknisophyllum consuitum*

Diameter:	
N.	6
M.	17.7
O.R.	14.5–20.0
S.D.	2.2
C.V.	12.2
$S.E._M$	.88
n/d:	
N.	6
M.	2.3
O.R.	1.9–2.8
S.D.	.3
C.V.	14.4
$S.E._M$	.14

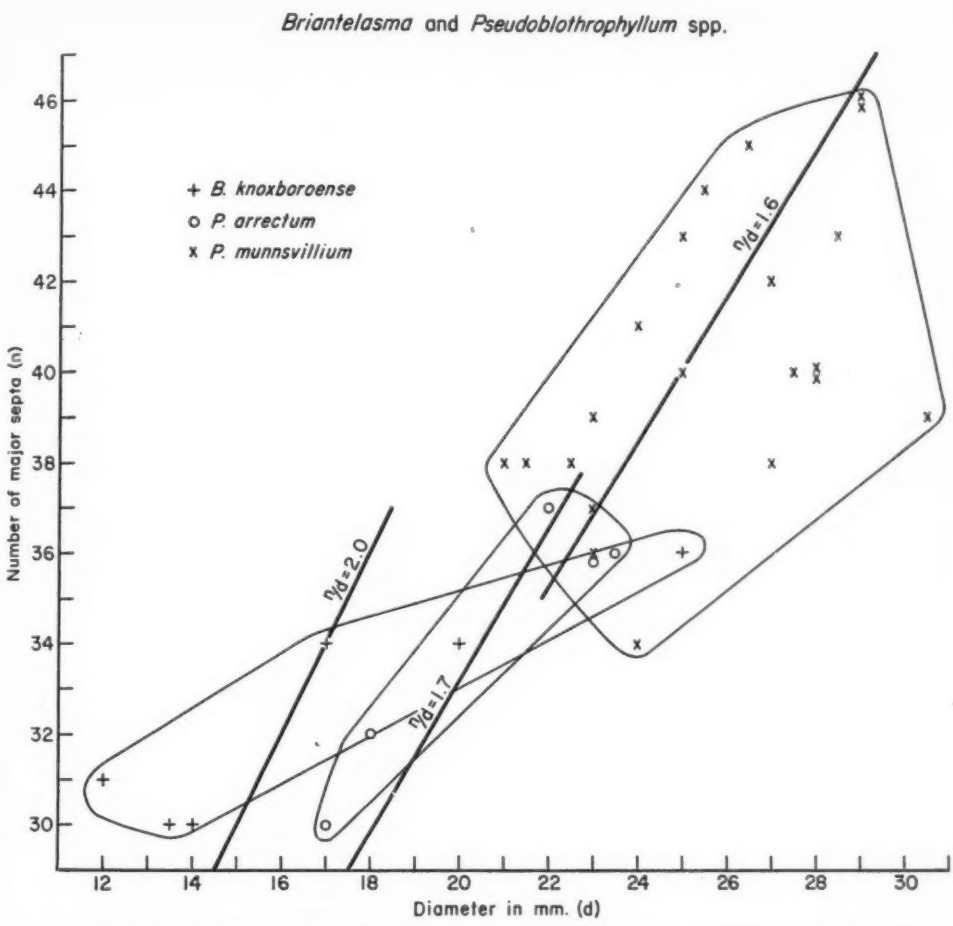
Tabularium diameter.—Length of minor septa, width of dissepimentarium or marginarium and diameter of tabularium are commonly cited in systematic descriptions of corals, but no examples of statistical analysis of these variables are known to the present author. In the species being considered the minor septa extend just to the inner edge of the marginarium so that an analysis of tabularium diameter with respect to total diameter should give results similar to study based on width of marginarium or length of minor septa. Tabularium diameter is picked for reasons of convenience.

Data are graphically presented in 3 ways: 1) scatter diagrams plotting tabularium diameter against total diameter, 2) tabularium ratio frequency curves, and 3) curves of average tabularium ratio per diameter class.

The scatter diagrams (text-figs. 21–27) are a direct means of showing overall variation in tabularium diameter, variation in tabularium diameter for a given total diameter, and the overall increase in tabularium diameter with total diameter. Each plotted point represents an individual that is presumed to be mature. The straight lines are plots of maximum, mean, and minimum tabularium ratio for each collection. The



TEXT-FIG. 6—*Briantelasma americanum.* Scatter diagram of number of major septa×diameter in 31 specimens from the Mosquito Point reef. Straight lines represent plots of mean, minimum, and maximum values of septal ratio for collection.

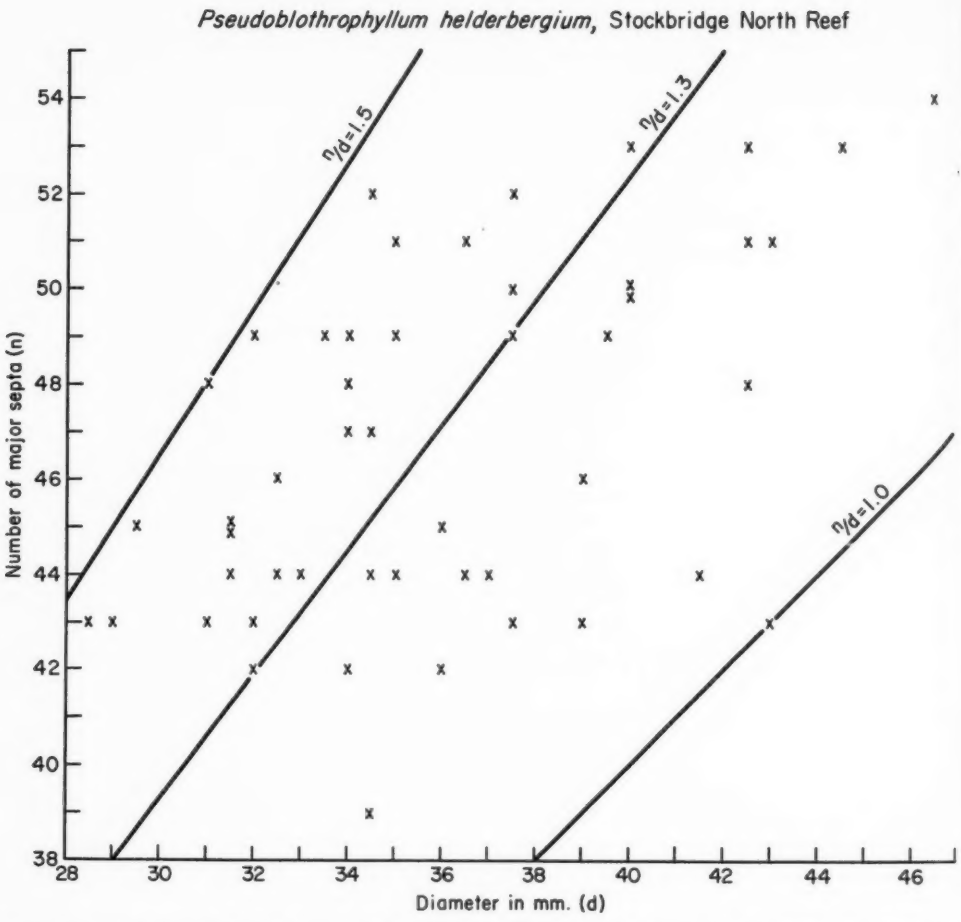


TEXT-FIG. 7—Scatter diagram of number of major septa X diameter in uncommon species of *Briantelasma* and *Pseudoblothrophyllum*. Polygons enclose all plots of each species; straight lines represent mean septal ratios.

parallelism of these lines with the general trend of plotted points shows that the tabularium ratio is independent of diameter. This is more accurately shown by the curves of average tabularium ratio per diameter class (text-fig. 28) which generally parallel the X-axis. The tabularium ratio remains relatively constant with increasing diameter although there is considerable variation in the ratio at any given diameter.

Ontogenetic variation in tabularium ratio differs significantly from individual variation in adults. In the conical parts of the coralla of *S. variabilis* and *P. helderbergium* the tabularium ratio is relatively high. With growth the tabularium ratio decreases with increasing diameter in contrast to variation between adults in which the mean tabularium ratio is constant with increasing diameter (text-fig. 28).

Serial measurements of tabularium ratio for a single specimen of *P. helderbergium* are shown on text-figure 29. Measurements were made at 2 mm. intervals on the longitudinal section of specimen USNM 137164. Such measurements are less accurate than the measurements from transverse sections on which the other tabularium data is based because of the difficulty of cutting the specimen exactly on the axial line. The specimen however, is large and straight (pl. 16, fig. 4) so sectioning difficulties were minimized.

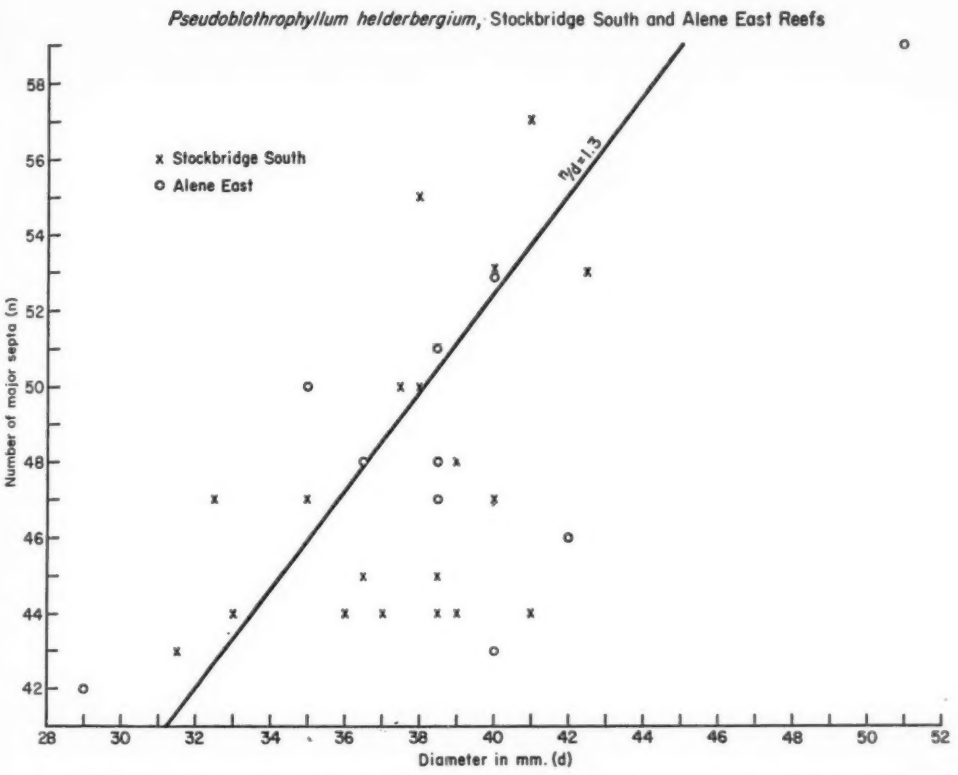


TEXT-FIG. *8*—*Pseudoblothrophyllum helderbergium*. Scatter diagram of number of major septa X diameter in 49 specimens from the Stockbridge North reef. Straight lines represent plots of mean, minimum, and maximum values of septal ratio for collection.

Text-figure 29 (top curve) shows that the tabularium ratio in the conical portion of the corallum decreases with increasing diameter (text-fig. 29, measurements 1–25). The apex of the coral is missing but in the conical 5 cm. preserved, the tabularium ratio decreases from .81 to .53. This is in contrast to the next 4 cm. (measurements 25–45) which shows irregular tabularium ratio variation from .58 to .45. Interestingly enough a good part of the cylindrical zone variation occurs in the uppermost centimeter of the corallum. This correlates with a marked decrease in tabularium diameter (text-fig. 29, lower curve) and may represent a gerontic stage not seen in most individuals.

Qualitative observations of many specimens and detailed analysis of data based on 3 to 5 serial transverse sections from each of 15 other specimens of *P. helderbergium* indicate that the ontogenetic trend shown on text-figure 29 is typical of the species.

Text-figure 29 shows that the tabularium diameter is relatively unaffected by the irregular expansions and contractions of the exterior and indicates that some of the variation within individuals in cylindrical stage tabularium ratio is a product of the external rugosity which is certainly environmentally controlled. However, variation between



TEXT-FIG. *9—Pseudoblothrophyllum helderbergium*. Scatter diagram of number of major septa × diameter in 19 specimens from the Stockbridge South and 10 specimens from the Alene East reefs. The straight line represents the plot of the mean septal ratio for both collections.

adults in tabularium diameter is approximately the same as variation between adults in total diameter (table 7).

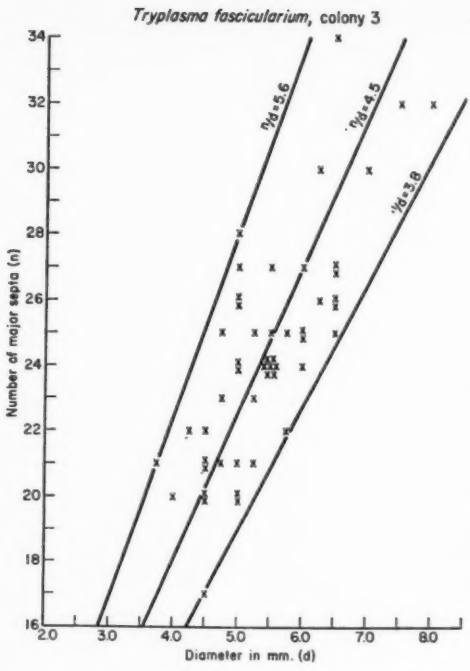
The tabularium ratio frequency curves (text-figs. 30–33) show that the tabularium ratio has an approximately normal distribution in the 3 common solitary coral species. Tabularium ratios for *Tryplasma fasciculare* were not calculated because of the very narrow marginarium in this species.

Other characters.—In this study emphasis is placed on septal and tabularium ratios because both can be conveniently measured in easily obtained transverse sections. Other measurable characters that could be studied are length of major septa and spacing of tabulae. Both would be difficult to analyze as variation within an individual is extreme.

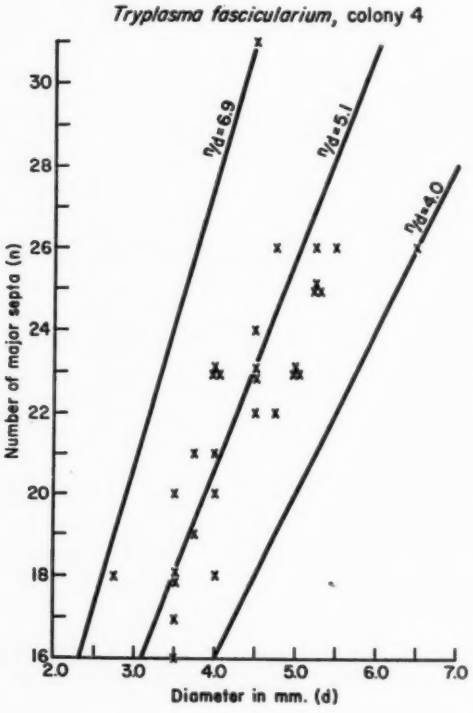
Other characters are important but do not lend themselves to quantitative analysis. Most significant in the present fauna is degree of filling of tabularia with stereoplasm. Others are shape of tabulae, external shape and markings and degree of development of amplexoid tendency (in *S. variabilis*).

All of these characters have been given some attention and qualitative statement on their variation will be found in the systematic descriptions.

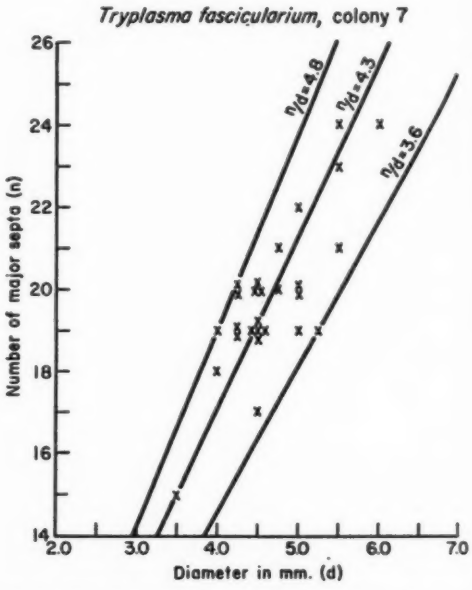
Variation within colonies.—Colonial corals differ from solitary corals in that most individuals in a given colony are reproduced asexually by another individual in the colony, only the founder (initial) corallite having been reproduced sexually. This suggests that genotypic variation within a colony should be less than variation within a population of solitary rugose corals which are presumably all produced sexually. How-



TEXT-FIG. *10—Tryplasma fascicularium.* Scatter diagram of number of septa×diameter in 50 individuals of colony 3 (table 5). Straight lines represent plots of mean, minimum and maximum values of septal ratio for colony.



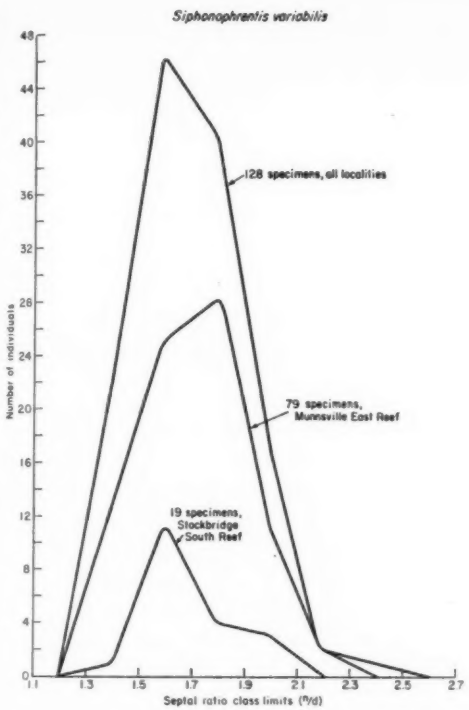
TEXT-FIG. *11—Tryplasma fascicularium.* Scatter diagram of number of major septa×diameter in 30 individuals of colony 4 (table 5). Straight lines represent plots of mean, minimum and maximum values of septal ratio for colony.



TEXT-FIG. *12—Tryplasma fascicularium.* Scatter diagram of number of major septa×diameter in 27 individuals of colony 7 (table 5). Straight lines represent plots of mean, minimum and maximum values of septal ratio for colony.

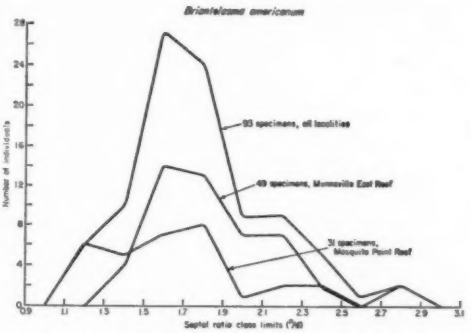
ever, greater genotypic variation may exist in a colony (or apparent colony) either through intergrowth of two or more adjacent colonies (not likely to be recognized in usually incomplete placeloid coralla) or through the fusion of several primary (sexually reproduced) polyps before or during an early stage of colony formation (see Stephenson, 1931, p. 124–125, for discussion of this phenomena in Recent corals).

Septal ratio coefficients of variation are approximately the same in colonies of *T. fascicularia* (with cylindrical corallites) and

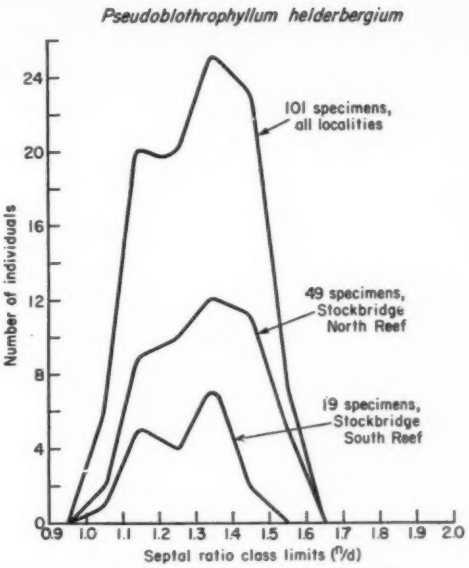

Siphonophrentis variabilis
128 specimens, all localities
79 specimens, Munnsville East Reef
19 specimens, Stockbridge South Reef
Number of individuals
Septal ratio class limits (d/d)

TEXT-FIG. *13—Siphonophrentis variabilis.* Frequency distribution of septal ratios in indicated collections.

in collections of the solitary cylindrical corals *S. variabilis* and *P. helderbergium* (table 7) although much less than in the conical *B. americanum,* as previously discussed. The fact that the coefficient of variation of the septal ratio is the same within the coralla of a colonial form and in popula-

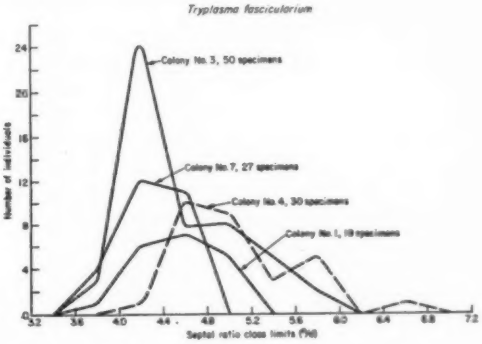


TEXT-FIG. *14—Briantelasma americanum.* Frequency distribution of septal ratios in indicated collections.

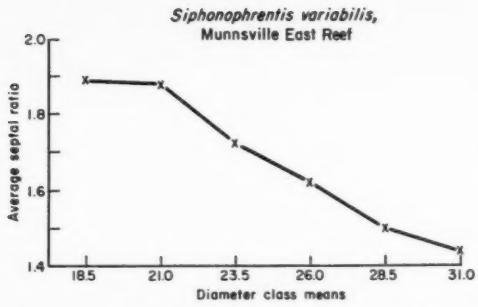

Pseudoblothrophyllum helderbergium
101 specimens, all localities
49 specimens, Stockbridge North Reef
19 specimens, Stockbridge South Reef
Number of individuals
Septal ratio class limits (d/d)

TEXT-FIG. *15—Pseudoblothrophyllum helderbergium.* Frequency distribution of septal ratios in indicated collections. Note that class interval is different from figures 13 and 14.

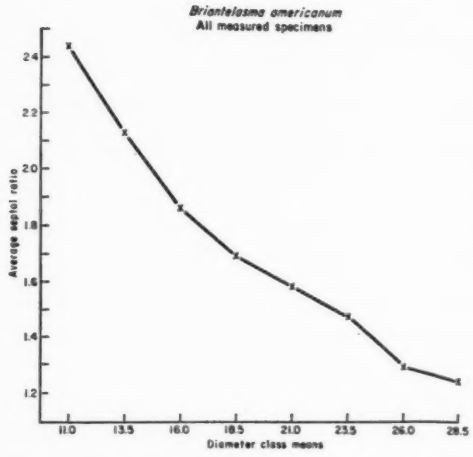
tions of solitary corals may be interpreted in three ways: 1) One could argue that the variation was mostly microenvironmentally induced since genotypic variation is limited in a colony and since ontogenetic variation is limited in cylindrical portions of corallites. 2) Alternately one could suggest that the variation is mostly due to random genetic differences between individuals, such variation in the colonies being due to intergrowth or fusion as described in the previous para-


Tryplasma fasciculorium
Colony No. 3, 50 specimens
Colony No. 7, 27 specimens
Colony No. 4, 30 specimens
Colony No. 1, 19 specimens
Number of individuals
Septal ratio class limits (d/d)

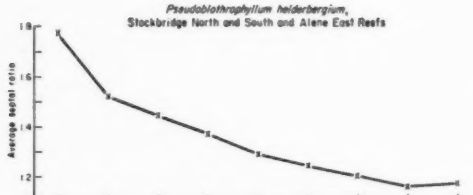
TEXT-FIG. *16—Tryplasma fasciculorium.* Frequency distribution of septal ratio in 4 colonies.



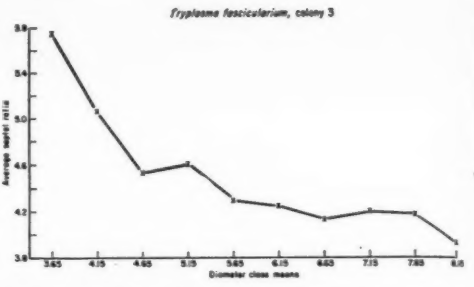
TEXT-FIG. *17—Siphonophrentis variabilis.* Curve showing decrease in average septal ratio with increasing diameter in 79 Munnsville East reef specimens.



TEXT-FIG, *18—Briantelasma americanum.* Curve showing marked decrease in average septal ratio with increasing diameter in 93 measured specimens.



TEXT-FIG. *19—Pseudoblothrophyllum helderbergium.* Curve showing decrease in average septal ratio with increasing diameter in 78 measured specimens.



TEXT-FIG. *20—Tryplasma fascicularium.* Curve showing general decrease in average septal ratio with increasing diameter in 50 individuals of colony 3.

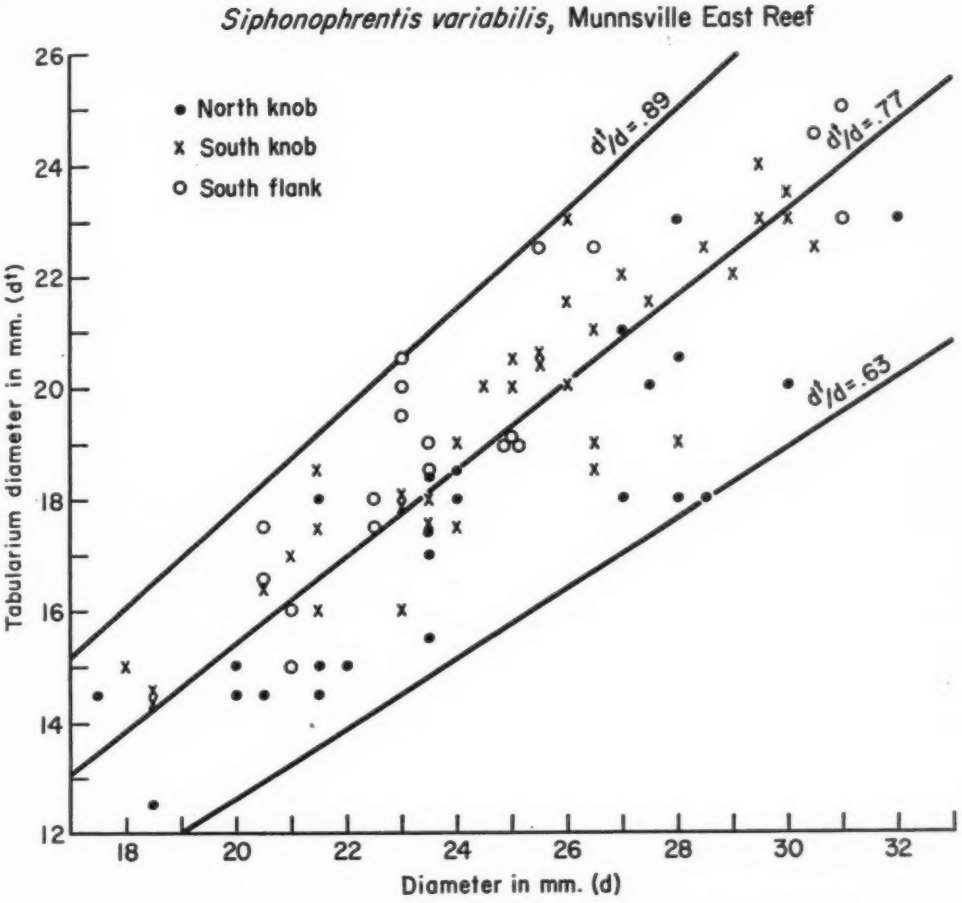
graph. 3) Finally the similar coefficients could be due to coincidence. It seems likely that random genetic variation is a factor in the solitary species and therefore in the colonial form as well (alternative 2) but microenvironmental differences (alternative 1) may have had some effect also. Coincidence (alternative 3) seems unlikely but only the study of a large number of additional forms will demonstrate this.

Variation between colonies of *T. fasciculariumis* indicated on table 5. Total statistics for the species are based on analysis of colony means, rather than on total individuals. The coefficients of variation of the colonies (not shown) are within the range of the coefficients of individual variation within colonies. Considerable additional work must be done on the statistics of variation within and between colonies before conclusions can be drawn.

Discrimination of species in Briantelasma and Pseudoblothrophyllum.—The Helderberg species here described were established on qualitative features with the partial exception of the uncommon species of *Briantelasma* and *Pseudoblothrophyllum.* Statistical methods are primarily used as a means of analyzing and comparing individual variation within species and populations.

The "open" and "closed" structure in *Briantelasma* is an obvious basis for species division on qualitative ground alone, but statistical analysis gave significant additional support to the separation of *B. americanum* and *B. knoxboroense.*

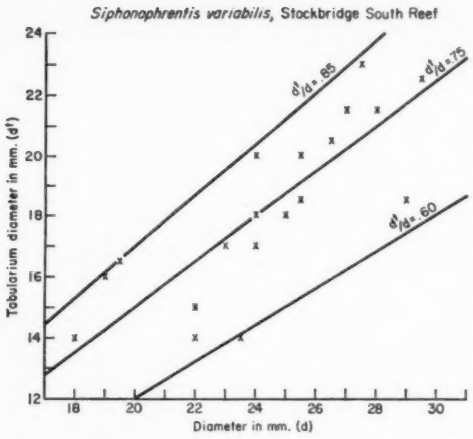
Briantelasma knoxboroense is known mainly from the Knoxboro reef where 10 specimens were collected along with 23 specimens of



TEXT-FIG. *21*—*Siphonophrentis variabilis*. Scatter diagram of tabularium diameter×total diameter in 79 specimens from the Munnsville East reef. Straight lines represent plots of mean, minimum and maximum values of tabularium ratio for collection.

B. americanum. Analysis of the total *Briantelasma* collected at Knoxboro showed the tabularium ratio range to extend considerably higher than in larger collections of *Briantelasma* (*B. americanum*) from other reefs. (Munnsville East and Mosquito Point, table 3). Differences between the 3 population means were analyzed according to the method described by Simpson and Roe (1939, p. 192). The Munnsville East and Mosquito Point reef samples were essentially the same according to the test but the Knoxboro sample differed significantly from both of the others. The tabularium ratio of the Knoxboro sample shows a bimodal frequency distribution (text-fig. 32) with the low point between nodes falling approximately at the upper limits of the tabularium ratio of *B. americanum* in the other samples. This offers the only practical way of separating *B. knoxboroense* from *B. americanum* but is not entirely satisfactory as the mean tabularium ratio for the residuum of *B. americanum* from Knoxboro is still a little high (table 2). The two species are closely allied but cannot be considered subspecies as they are found at the same locality.

Pseudoblothrophyllum arrectum is known only from the northern extremity of the Mosquito Point reef; *P. munnsvillium* occurs farther south on the same reef. Neither



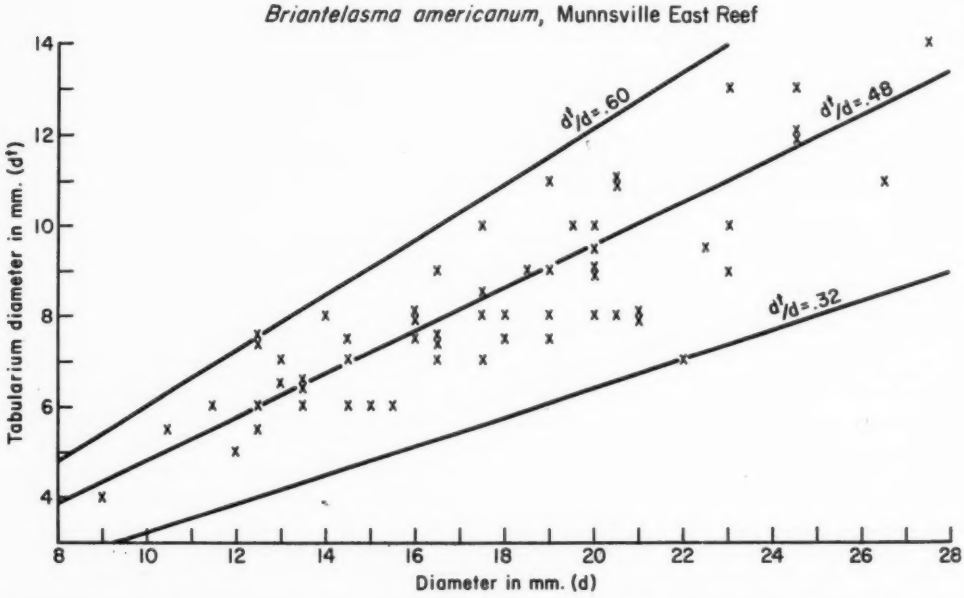
TEXT-FIG. 22—*Siphonophrentis variabilis*. Scatter diagram of tabularium diameter×total diameter in 19 specimens from the Stockbridge South reef. Straight lines represent plots of mean, minimum, and maximum values of tabularium ratio for collection.

species is common and both are recognized primarily on qualitative grounds although thin-sections of the two are very similar. A significant difference in tabularium ratio supports their separation as distinct species.

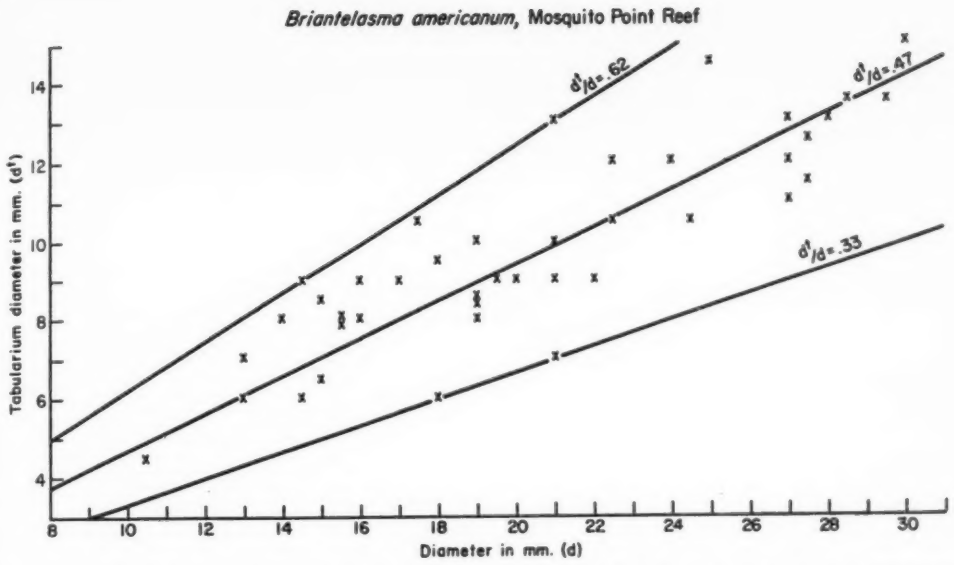
It may further be noted that *P. munnsvillium* and *B. knoxboroense* are both significantly different from *P. arrectum* and *B. americanum* in tabularium ratio. The first 2 are significantly different from each other in septal ratio but the last 2 can be clearly separated only on qualitatively treated characters.

Summary and Conclusions.—Statistics are a useful means of analyzing and expressing individual variation in rugose corals. In the present work, numbers of major septa, tabularium diameter, and total diameter are studied but other types of corals offer additional possibilities. Park (1955) analyzed 6 different characters and their relationships in a comprehensive study of a sample of the cylindrical *Aulophyllum fungites* from the Lower Carboniferous of Great Britain. The coefficients of variation for the several ratios tested are of the same order of magnitude as those found in the Helderberg corals, and the septal ratio (N. C. in Parks, 1955, p. 185) falls into the cylindrical grouping of the present fauna.

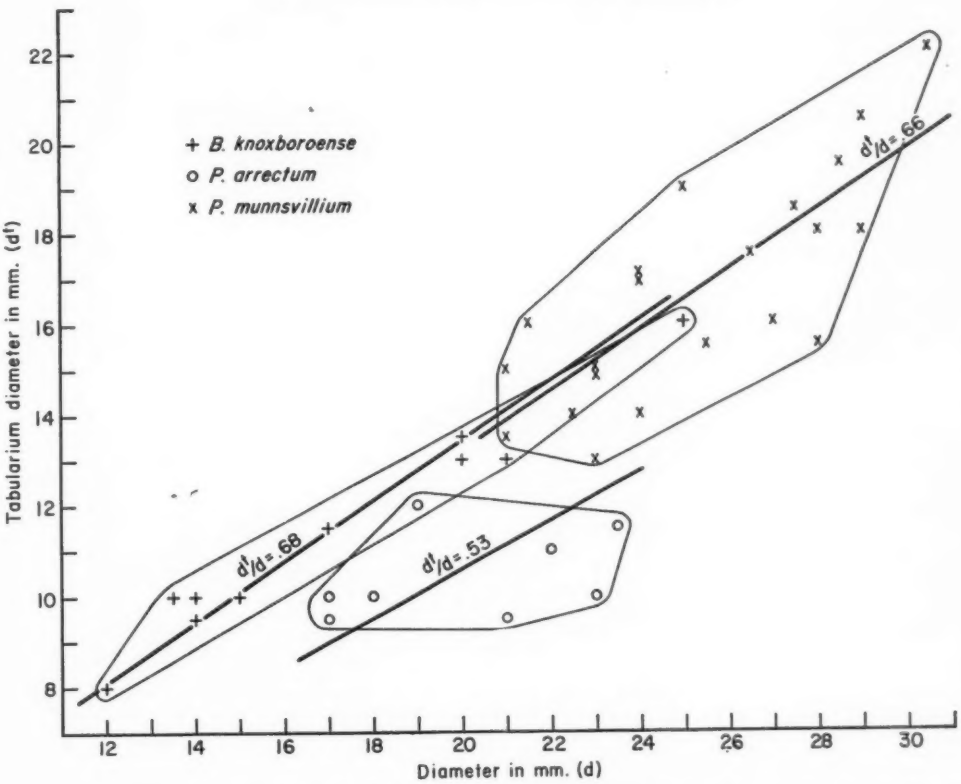
The coefficients of variation in the described species are high (table 7). This is partly due to the lack of control in selecting fossil specimens of the same age etc., for analysis (see Simpson and Roe, 1939,



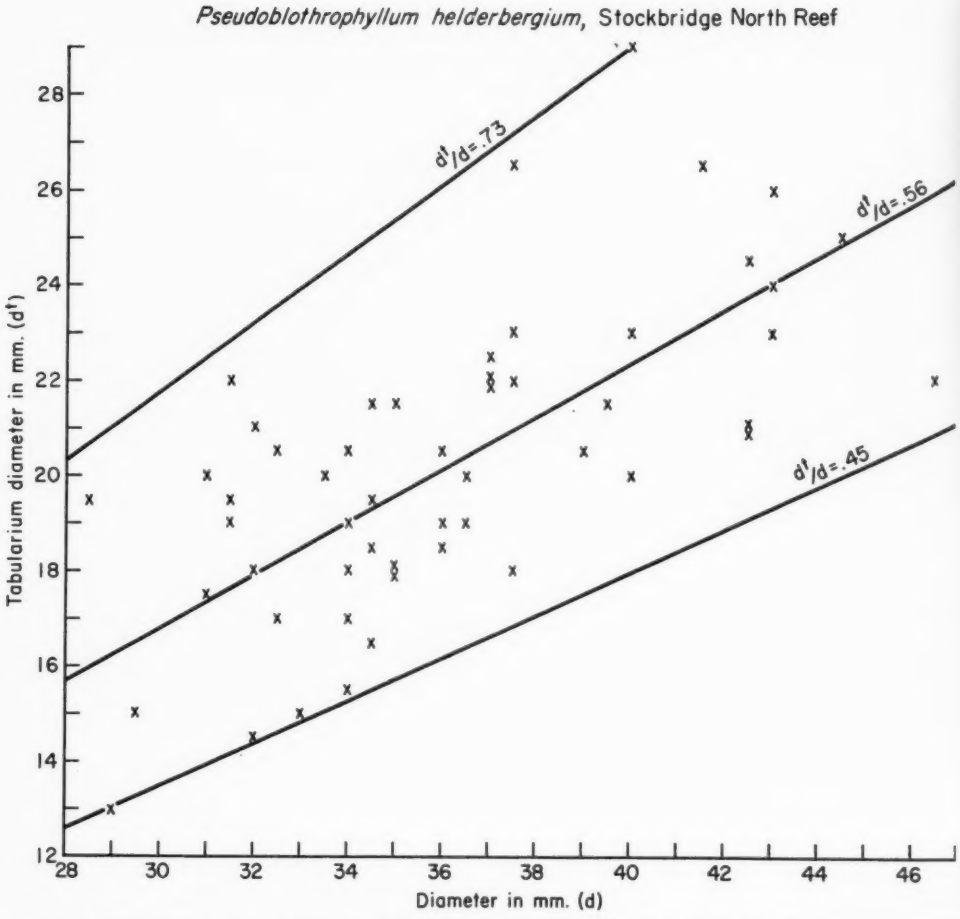
TEXT-FIG. 23—*Briantelasma americanum*. Scatter diagram of tabularium diameter×total diameter in 58 specimens from the Munnsville East reef. Straight lines represent plots of mean, minimum and maximum values of tabularium ratio for collection.



TEXT-FIG. *24*—*Briantelasma americanum*. Scatter diagram of tabularium diameter×total diameter in 41 specimens from the Mosquito Point reef. Straight lines represent plots of mean, minimum, and maximum values of tabularium ratio for collection.



TEXT-FIG. *25*—Scatter diagram of tabularium diameter×total diameter in uncommon species of *Briantelasma* and *Pseudoblothrophyllum*. Polygons enclose all plots of each species and straight lines represent mean tabularium ratios.



TEXT-FIG. *26—Pseudoblothrophyllum helderbergium.* Scatter diagram of tabularium diameter×total diameter in 53 specimens from the Stockbridge North reef. Straight lines represent plots of mean minimum, and maximum values of tabularium ratio for collection.

p. 122–128). However, it seems logical that variation should be large in coelenterates, because of the considerable control that environment has on skeleton size and shape in these animals.

The results of the analysis of individual

EXPLANATION OF PLATE 13

All figures ×1 unless otherwise indicated

FIGS. *1–17—Siphonophrentis variabilis,* n. sp.; *1–3*—Holotype, USNM 137151, Loc. 5; *1*, transverse section (×3), *2,3*, transverse and longitudinal sections; *4*—Paratype, USNM 137147, Loc 5; exterior showing talons; *5*—Paratype, NYSM 11064, Loc. 5; exterior; *6–8*—Paratype, NYSM 11067, Loc. 8; *6,7*, upper and lower transverse sections taken approximately 2 mm. apart showing greater length of septa in lower section, *8*, portion of upper section (×3); *9,10*—Paratype, NYSM, 11065, Loc. 5; lower and upper transverse sections (×1½); *11–13*—Paratype, USNM 137149, Loc. 5; *11,12*, transverse and longitudinal sections of specimen with unusually heavy deposits of stereoplasm, *13*, portion of transverse section (×3); *14*—Paratype, NYSM 137150, Loc. 5; transverse section of specimen with short septa; *15*—Paratype, NYSM, 11063, Loc. 11; broken specimen showing downbending of tabulae around cardinal septum (×1½); *16*—Paratype, USNM 137148, Loc. 5; exterior; *17*—Paratype, NYSM 11066, Loc. 5; longitudinal section.

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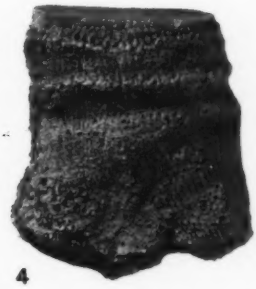
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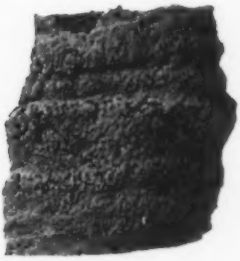
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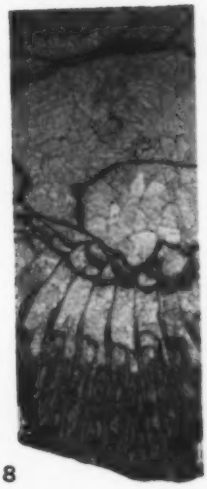
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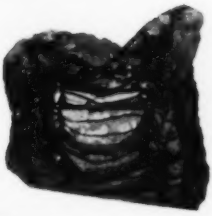
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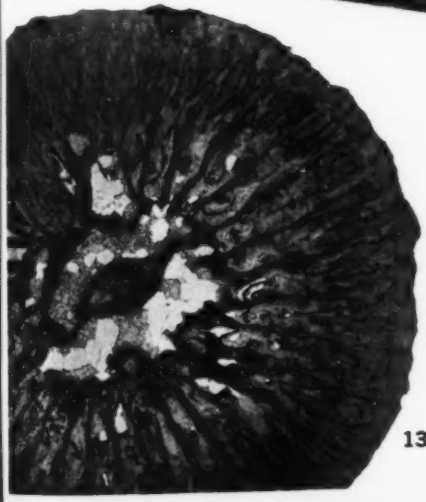
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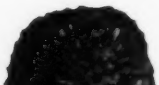
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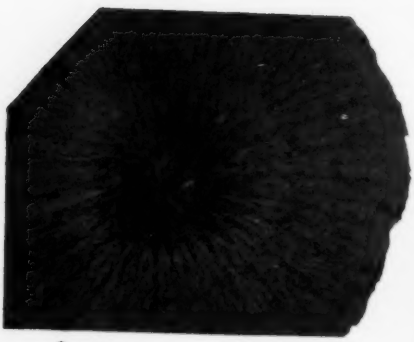
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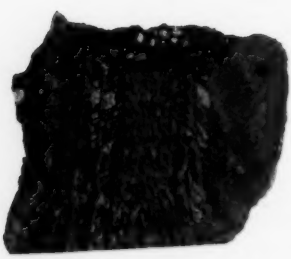
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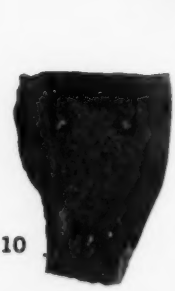
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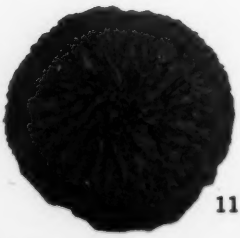
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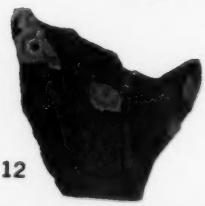
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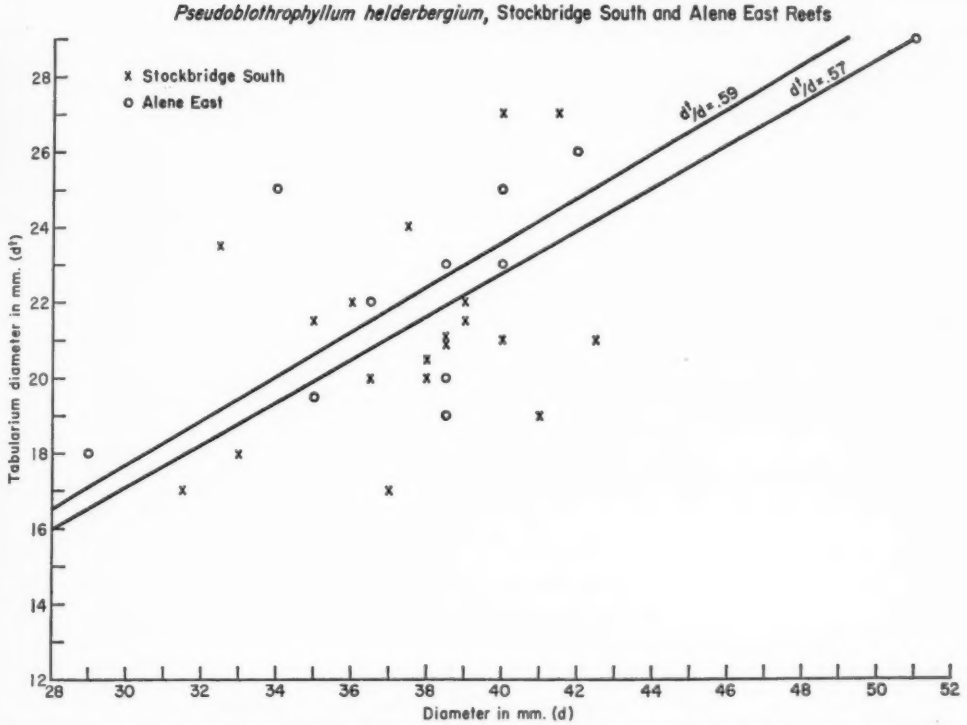


TEXT-FIG. *27—Pseudoblothrophyllum helderbergium.* Scatter diagram of tabularium diameter × total diameter in 19 specimens from the Stockbridge South reef (mean $d^t/d = .57$) and 11 specimens from the Alene East reef (mean $d^t/d = .59$). The straight lines represent plots of the mean tabularium ratios of the two collections.

variation in the described corals can be summarized as follows, but the applicability of these statements to rugose corals as a whole will not be known until detailed analyses are available for many additional species.

1. The fauna is ideal for a study of individual variation because the collections include a large number of individuals of a few species from a rock unit which is limited to a small geographic area and which represents a very short span of time.

2. In cylindrical corals ontogenetic variation can be largely eliminated from consideration by using data derived from cylindrical portions of corallites.

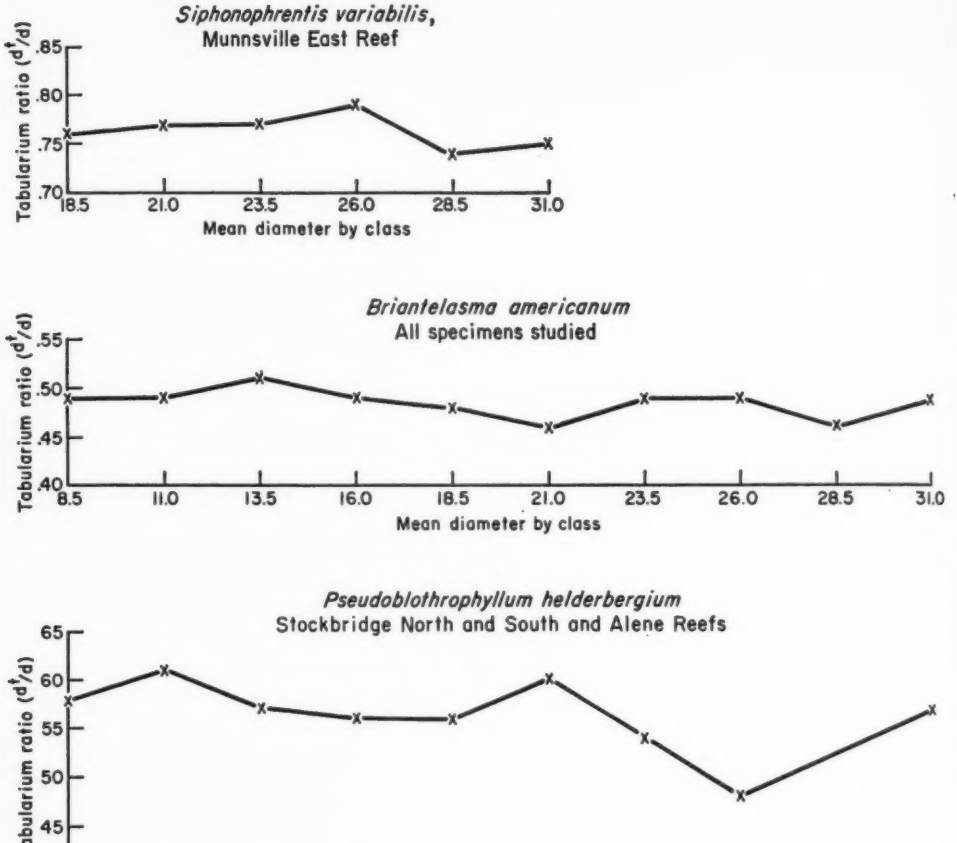
3. In conical corals ontogenetic variation can be partially eliminated from consideration by excluding from quantitative consideration obviously undersize individuals and by making all measurements in a transverse section just below the base of the calice.

4. Size (diameter) variation is no greater than variation in the size dependent ratios considered.

5. Among adults the mean septal ratio

EXPLANATION OF PLATE 14

FIGS. *1–14—Briantelasma americanum*, n. gen., n. sp. *1–4*—Holotype, NYSM 11069, loc. 4; serial transverse sections similarly oriented, *1*, ×3, *2–4*, ×1½; *5–7*—Paratype, USNM 137152, loc. 4; exterior views ×1½, *6*, calice, largely cleaned out showing broad axial platform and small periaxial fossula toward lower right; *8*—Paratype, USNM 137154, loc. 5; transverse section of completely filled specimen (×3); *9*—Paratype, NYSM 11071, loc. 5; longitudinal section (×1½); *10*—Paratype, NYSM 11070, loc. 5; longitudinal section (×1); *11*—Paratype, USNM 137155, loc. 4; neanic transverse section (×3); *12*—Paratype, USNM type, USNM 137153, loc. 5; longitudinal section (×1); *13,14*—Paratype, NYSM 11068, loc. 4; lower and upper transverse sections (×3).



TEXT-FIG. *28*—Curves showing relative constancy of tabularium ratio with increasing diameter in the 3 common species of solitary corals.

(number of major septa/diameter) decreases with increasing diameter.

6. An ontogenetic decrease in septal ratio with increasing diameter is characteristic.

7. Among adults the mean tabularium ratio (tabularium diameter/total diameter) is constant with increasing diameter.

8. Ontogenetically there is a marked decrease in the tabularium ratio with increasing diameter.

9. Coefficients of variation are generally much higher in the conical species than in the cylindrical species.

10. Coefficients of variation of cylindrical individuals within a colony are similar to coefficients of variation within whole collections of solitary cylindrical corals. This is interpreted as indicating that genotypic variation in the colonial form is increased by individuals being derived from more than one founder (sexually produced) individual.

11. The recognition of more than one species of *Briantelasma* and of *Pseudoblothrophyllum* is supported by biometrical data although the species are based primarily on qualitative analysis.

GEOGRAPHIC FAUNAL VARIATION

Table 8 shows the known geographic distribution of the described reef corals. The reefs are listed from east to west and as a matter of convenience are grouped into 3 areas (text-fig. 1, index map). The western area contains only one small reef and data

TABLE 7—COEFFICIENTS OF VARIATION OF ALL REEF SPECIES

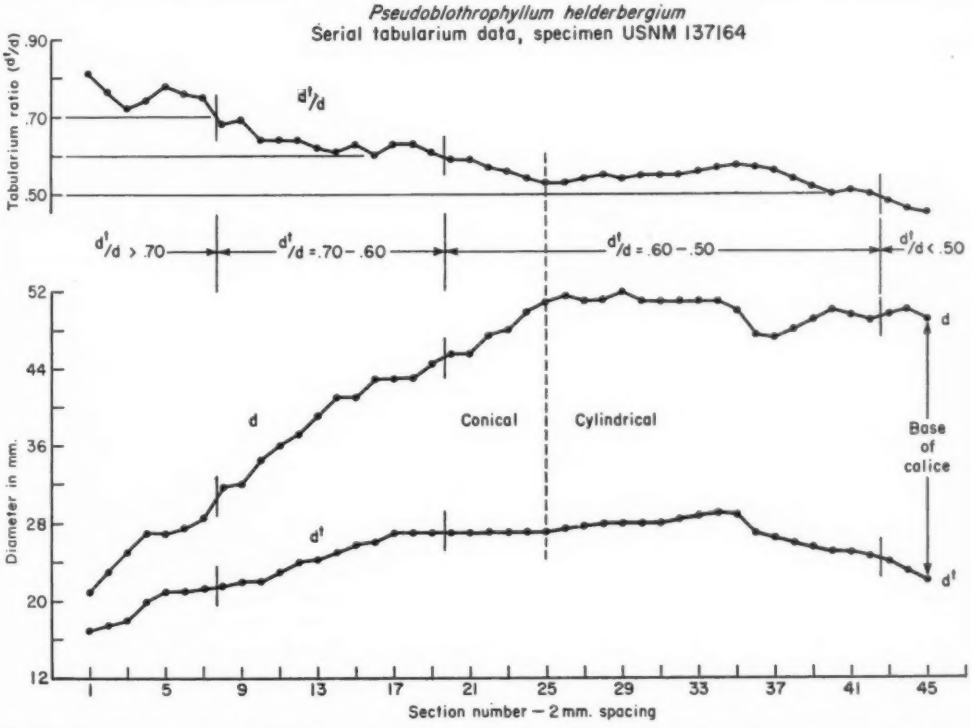
	d	*n/d*	d^t	d^t/d
Conical species:				
Briantelasma americanum	26.2	20.6	27.5	15.0
B. knoxboroense	31.6	18.3	20.9	5.1
Cylindrical species:				
Siphonophrentis variabilis	15.2	12.1	16.3	8.4
Pseudoblothrophyllum helderbergium	13.4	10.5	15.5	12.0
P. arrectum	13.2	6.7	9.0	13.2
P. munnsvillium	10.5	8.8	14.0	8.6
Tryplasma fasciculariun (average C.V. of 8 colonies)	13.7	9.3		

is inadequate. The central and eastern areas each contain several reefs and collections should be fairly representative.

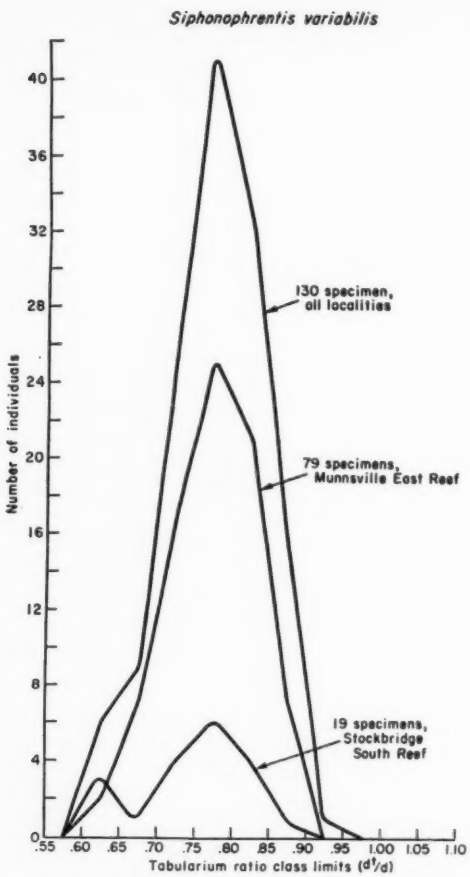
Most striking is the prevalence of *Briantelasma americanum* in the eastern area (61 percent of identified solitary corals) and of *Pseudoblothrophyllum heldergerbium* in the central (74 percent) and western areas (table 8B). *Siphonophrentis variabilis* is more generally distributed in all 3 areas. *Tryplasma fascicularium* (colonial and not included in percentages of table 8B) is widely distributed on all reefs and is the only reef species known from the non-reef facies of the Coeymans limestone.

The distribution of the less common species may or may not be significant. *P. munnsvillium* is widely distributed but nowhere common. *P. arrectum* and *B. knoxborboroense* are for all practical purposes known from single localities, although 3 other specimens are questionably referred to the latter. *Fletcherina incognita* is known from one or few coralla and need not be further considered.

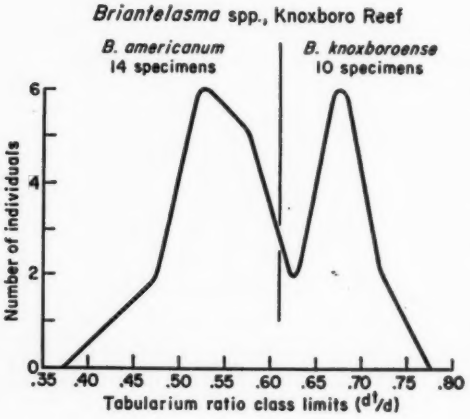
Tables 1, 2, 4, and 6 suggest little if any important variation between different local populations of the common corals. The inter-reef areas apparently offered no signif-

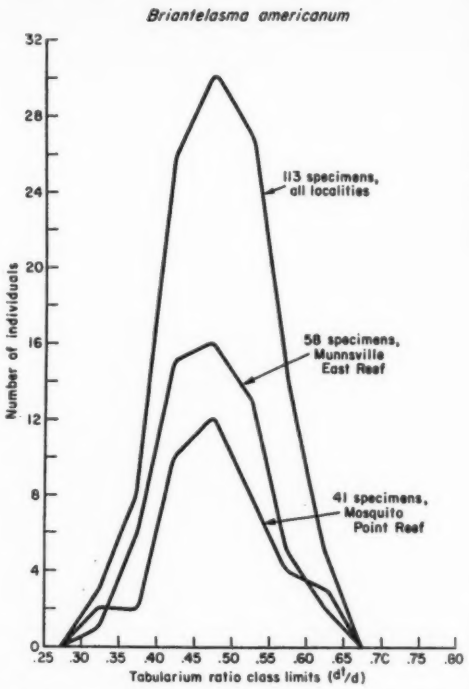


TEXT-FIG. *29*—*Pseudoblothrophyllum helderbergium* ontogeny. Plots of serial measurements of tabularium ratio (upper curve), diameter (middle curve) and tabularium diameter (lower curve). Specimen USNM 137169; loc. 9, Lenox reef.


Siphonophrentis variabilis
Number of individuals
Tabularium ratio class limits (d¹/d)
130 specimen, all localities
79 specimens, Munnsville East Reef
19 specimens, Stockbridge South Reef

TEXT-FIG. *30—Siphonophrentis variabilis.* Frequency distribution of tabularium ratios in indicated collections.




Briantelasma americanum
Number of individuals
Tabularium ratio class limits (d¹/d)
113 specimens, all localities
58 specimens, Munnsville East Reef
41 specimens, Mosquito Point Reef

TEXT-FIG. *31—Briantelasma americanum.* Frequency distribution of tabularium ratios in indicated collections.

icant barrier to the movement of larvae from one reef to another or even one area to the other in the case of *S. variabilis* and *T. fascicularium.* The species of *Briantelasma* and *Pseudoblothrophyllum* may have found it more difficult to move from area to area.

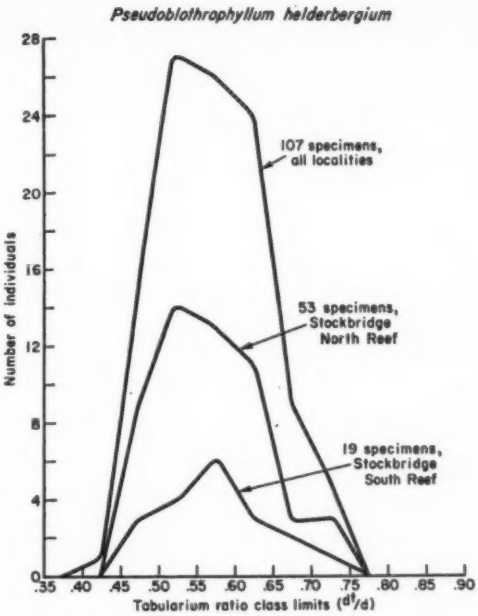
The possibility of age difference between reef areas cannot be ruled out. Rickard (1955) has suggested that the Coeymans limestone becomes progressively younger toward the west in New York. This might make the central reef group slightly younger than the eastern, and might account for the above noted differences in the coral faunas.

LOCALITY DESCRIPTIONS

The localities from which corals are described are briefly listed from east to west. All represent exposures of the Coeymans limestone in New York, and all but the first

TEXT-FIG. *32—Briantelasma* spp. Bimodal distribution of tabularium ratios in all specimens from the Knoxboro reef. See text discussion of species discrimination in *Briantelasma.*

TEXT-FIG. *33—Pseudoblothrophyllum helderbergium.* Ferquency distribution tabularium of ratios in indicated collections.



two are in the reef facies. The reefs were named by Rickard and the author during field work because names are easier to remember than numbers. The names are recorded here because it is believed that this principle applies in text discussion also. The names are names of outcrops and not stratigraphic terms. Collection numbers refer to the U. S. Geological Survey, Silurian-Devonian catalog. Corresponding numbers for the collections made while employed by the New York State Museum are not recorded because they were assigned in accordance with the author's own numbering system and are available only in personal notes and files. Specimen and collection ownership is indicated in the systematic section by museum number assignment.

1. Hillside, 0.4 mile southwest of Days

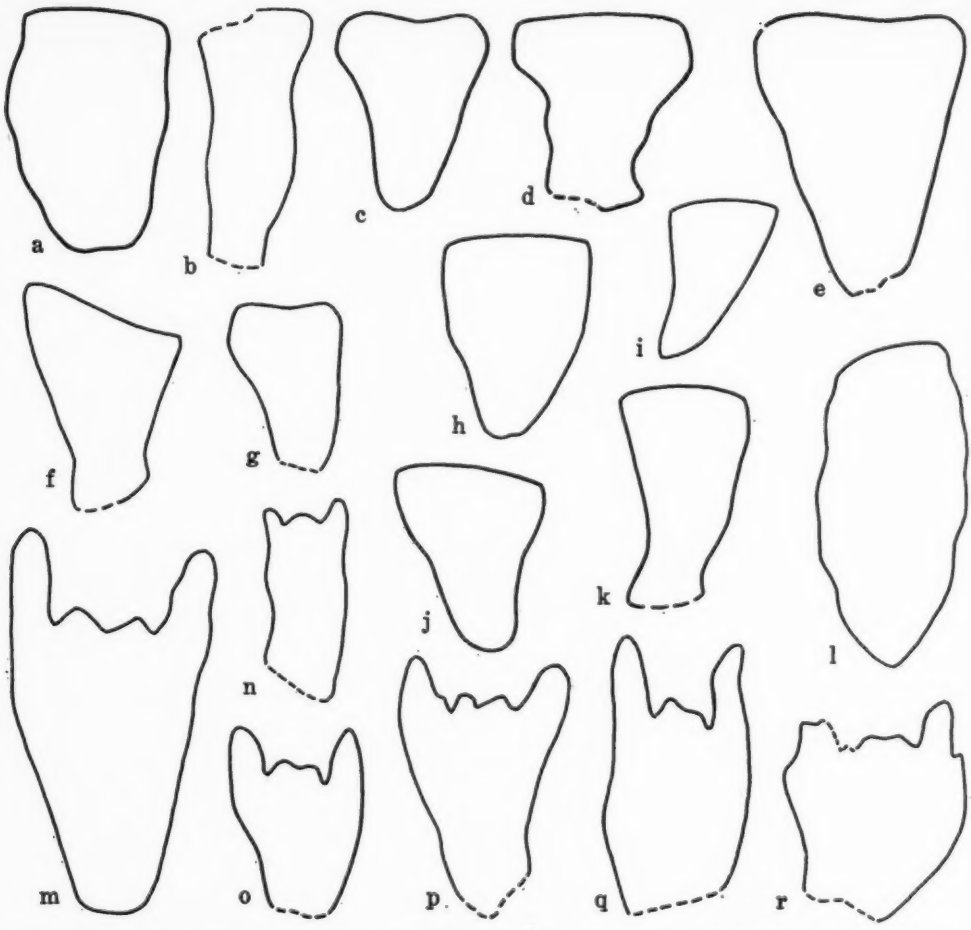
TABLE 8—SPECIES DISTRIBUTION DATA

A. Numbers of Coralla Identified

	Siphonophreitis variabilis	*Briantelasma americanum*	*B. knoxboroense*	*Pseudoblothrophyllum helderbergium*	*P. munnsvillium*	*P. arrectum*	*Fletcherina incognita*	*Tryplasma fasciculatum*
Non-reef								1
Knoxboro reef		21	10					2
Mosquito Pt. reef	10	96		6	9	8		13
Munnsville E. reef								
north knob	24	35		9				7
south knob	38	63	2?	2				1
south flank	20			2				3
Munsville W. reef								2
Stockbridge N. reef	8			72	2		1	5
Stockbridge S. reef	19	1?		30	8			2
Lenox reef	6		1?	14	2			3
Alene E. reef	1			22				4
Alene W. reef				4	1			1
Bishop Brook reef	6			5				3

B. Percentage Distribution by Areas
(% of total solitary corals identified)

Eastern Area	25.9	60.6	2.8	5.4	2.5	2.3		
Central Area	17.8			74.3	6.8			



TEXT-FIG. *34*—*Briantelasma americanum* shape variation. a–l, external outlines of whole specimens; m–r, outlines of longitudinal sections showing shape of calice in addition. Incomplete apices indicated by dashed lines. Specimens deposited as follows, locality number in parentheses; hyphens indicate repetition of data: a, NYSM 11072 (4); b, -73 (5); c, -74 (4); d, -75 (4); e, -76 (4); f, USNM 137152 (4); g, -56 (5); h, -57 (5); i, -58 (5); j, -59 (5); k, -60 (5); l, -61 (4); m, -62 (4); n, -63 (5); o, NYSM 11070 (5); p, -77 (5); q, -78 (5); r, -79 (5). Outlines by Elinor Stromberg. All drawings $\times\frac{9}{10}$.

Corners, West Winfield 7½ minute quadrangle, Herkimer Co.; non reef (4603).

2. Pasture, 1.8 miles west of Deansboro, at north edge of Oriskany Falls 7½ minute quadrangle, Oneida Co.; non reef, (4653).

3. Knoxboro reef. Pasture, 0.4 mile northwest of Knoxboro, Munnsville 7½ minute quadrangle, Oneida Co. (4634).

4. Mosquito Point reef. Just east of north-south portion of road, 0.3 mile northeast of Munns, Munnsville 7½ minute quadrangle, Madison Co. (4628–4633).

5. Munnsville East reef. In and north of orchard, 0.8 mile, south-southeast of the village of Munnsville, Munnsville 7½ minute quadrangle, Madison Co. (4624–4627, 4654–4656).

6. Munnsville West reef. Just north of road, 1 mile west of the village of Munnsville, Munnsville 7½ minute quadrangle, Madison Co. (4609).

7. Stockbridge North reef. Forms northernmost summit of West Stockbridge Hill, Oneida 7½ minute quadrangle, Madison Co. (4665–4668.

8. Stockbridge South reef. Forms more

subdued summit 0.45 miles south of above, Oneida 7½ minute quadrangle, Madison Co. (4613–4618, 4657–4659).

9. Lenox reef. Small knobs in north projecting woods, 2.2 miles south of Lenox, and 1.7 miles east-northeast of Alene, Oneida 7½ minute quadrangle, Madison Co. (4622–4623).

10. Alene East and West reefs. On south side of road, 0.65 and 0.25 miles east of Alene-Clockville road, 0.8 miles north of Alene, Oneida 7½ minute quadrangle, Madison Co. (4620 and 4621).

11. Bishop Brook "reef." In woods, 0.7 miles northeast of main intersection in the village of Manlius, Manlius 7½ minute quadrangle, Onondaga Co. (4661–4662). This is in the Bishop Brook limestone of Smith (1929, p. 32).

SYSTEMATIC DESCRIPTIONS

In the following section depositories are indicated as follows: USNM, United States National Museum, Washington 25, D. C.; NYSM, New York State Museum, Albany 1, New York. Collection numbers are from the United States Geological Survey, Silurian-Devonian catalog (USGS-SD). Locality numbers are arbitrarily assigned as indicated in the preceeding section and on the index map (text-fig. 1).

Genus SIPHONOPHRENTIS O'Connell, 1914

Siphonophrentis O'Connell, 1914, p. 187,190,191; Stumm, 1949, p. 12–13; Wang, 1950, p. 214; Hill, 1956, p. 270.
Breviphrentis Stumm, 1949, p. 13–14; Hill, 1956, p. 271.

Type species.—By original designation, *Caryophyllia gigantea* Lesueur, 1821, p. 296,297.

Horizon and locality of type species.—Onondaga limestone (upper Lower or lower Middle Devonian), Herkimer or Otsego County, New York.

Diagnosis.—Simple, ceratoid to cylindrical corals with amplexoid septa withdrawn from axis except on and just above upper surfaces of tabulae. Tabulae dome-shaped, flat or concave axially, depressed at the fossula. No axial structure or dissepiments.

Remarks.—*Breviphrentis* Stumm, is very close to *Siphonophrentis*. Stumm (1949, p. 14) separated the former as having "no downwarping of tabulae in vicinity of fossula," but on the basis of more recent work has rejected the separation (written communication, 1957). His illustrations of *Amplexus invaginatus*, Stumm (1937, pl. 54, fig. 2a,b) type species of *Breviphrentis*, strongly suggest the presence of a U-shaped fossular boundary indicative of tabular downwarping.

SIPHONOPHRENTIS VARIABILIS n. sp.
Pl. 13, figs. 1–17

Diagnosis.—*Siphonophrentis* with comparatively long major septa and close spaced tabulae that are distally concave at axis; marginarium formed by infilling with stereoplasm.

External features.—Simple, medium sized, cylindrical corals. Dimensions of apparently mature individuals: diameter of corallum at base of calice, 17 to 37 mm., average 24.7 mm.; length of cylindrical portion, 2 to 15 cm.; length of expanding (conical) portion 2–4 cm. Exterior gently annulated showing alternate periods of expansion and contraction at irregular intervals; outer surface of epitheca with broad septal grooves which mark the positions of both major and minor septa. Broad talons at apical ends of many specimens indicate an erect growth position and cementation to a hard substrate for at least these individuals.

Calice known only in sections; moderately deep and steep sided, depth equals one-half to three-fourths diameter; floor gently or very concave depending on shape of uppermost tabula. Transverse sections through the calice show that the major septa project 2–3 mm. from the wall of the calice, the minor septa being slightly shorter; the nature of the septa on calice floor not known. A cardinal fossula is formed by downbending of the tabulae around a short cardinal septum.

Internal features.—Transverse sections throughout the cylindrical portion of corallum show extremely variable structure. Septa radially arranged, amplexoid; major extend from less than one-half to nearly the full distance to the axis depending in part on the position of the section relative to a tabula; minimum length varies in different individuals from one-half to three-fourths the radius. Major septa number 31–51, but average 41.5 in sections of average diameter. Minor septa very short, from two-tenths to

one-third the radius. Cardinal fossula formed by short cardinal septum around which the tabulae bend down so as to present a U-shape in sections which intersect this area.

Peripheral stereozone formed by dilation of peripheral portions of septa and infilling with additional stereoplasm, varies in width from one-tenth to one-third the radius; varies somewhat within an individual and even within a section. Where stereozone is well developed the minor septa extend just inside the zone; with a narrower stereozone the minor septa are more prominent. No axial structure.

Septal microstructure suggests monacanthine septa with lamellar stereoplasmic deposits in peripheral areas as described in the general morphology section.

Longitudinal sections show the peripheral stereozone and numerous, variably spaced tabulae. The tabulae are axially concave, periaxially convex and peripherally depressed forming a smooth M-shaped curve in section. Degree of concavity and convexity extremely variable within and between individuals. No dissepiments.

Remarks.—The above description is based on 130 incomplete and complete specimens from all three reef areas. Individual variation in the Munnsville East reef collections is representative of variation in the species as a whole. Scatter diagrams (Text-figs. 2–4,21–22) and table 1 show the nature and extent of such variation. In addition table 1 shows the nature of variation between two of the collections (local populations). It is interesting but of questionable significance that the forms with a wider stereozone are more numerous to the north in the Munnsville East reef and to the east in the reef area as a whole. Spatial distribution is shown on table 8.

A small number of trochoid and ceratoid corals from various collections are sufficiently like the conical portions of cylindrical specimens to suggest that they represent immature individuals of the same species. Septal ratio is larger in proportion to smaller size (text-fig. 4) and other differences also are a function of size or growth stage and found in the immature portions of large individuals.

S. variabilis differs from the type species of *Siphonophrentis*, *S. gigantea*, in its smaller size and in having the generic characters more weakly developed. *S. gigantea* has very amplexoid septa, a strong fossula, and essentially flat tabulae. *S. halli* (Edwards and Haime), 1851, from the Hamilton Group in New York, is like *S. gigantea* but with axially concave septa.

S. variabilis differs from previously described species assigned to *Breviphrentis* in the presence of a peripheral stereozone. Forms of *S. variabilis* with a narrow stereozone are still distinguishable from other species by the relatively long major septa and the shape of the tabulae. *B. invaginatus* (Stumm), 1937, appears to have more and shorter septa and flatter tabulae. *B. mirabilis* (Billings) 1874, has a very narrow epitheca in addition to flat tabulae and very short septa. *B. yandelli* (Milne-Edwards and Haime), 1851, also has very short septa.

Previously described species of *Siphonophrentis* and *Breviphrentis* are from rocks of Onondaga and Hamilton age in Nevada, Indiana-Kentucky, Ohio, Ontario and New York. *S. variabilis* represents the earliest species of the genus yet described and extends the range of the genus downward to include most of Helderberg time (lower Lower Devonian). It is possible that *S. variabilis* represents the stem from which the later forms evolved. The extreme variation within the species, especially with regard to the amplexoid tendency of the septa may support such an idea. Hill (1934, p. 94–96) suggested that individual variation represents weak expression of evolutionary trends common to all corals. The development of amplexoid septa is such a trend and may be weakly developed in early members of a

EXPLANATION OF PLATE 15

All figures ×1 unless otherwise indicated

FIGS. *1–12*—*Pseudoblothrophyllum helderbergium*, n. gen., n. sp. *1–5*—Paratype, NYSM 11082, loc. 7; serial transverse sections (similarly oriented) through conical and lower cylindrical portions of corallum; *6*—Paratype, USNM 137167, loc. 5; longitudinal section of juvenile individual; *7–12*—Holotype, NYSM 11081, loc. 4; *7*, longitudinal section, *8–10*, transverse sections through cylindrical and conical portions respectively, *11,12*, enlargement of parts of figs. *9* and *7* (×3).

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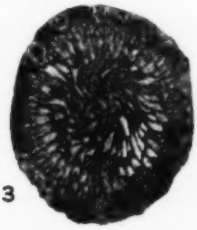
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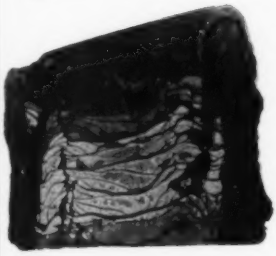
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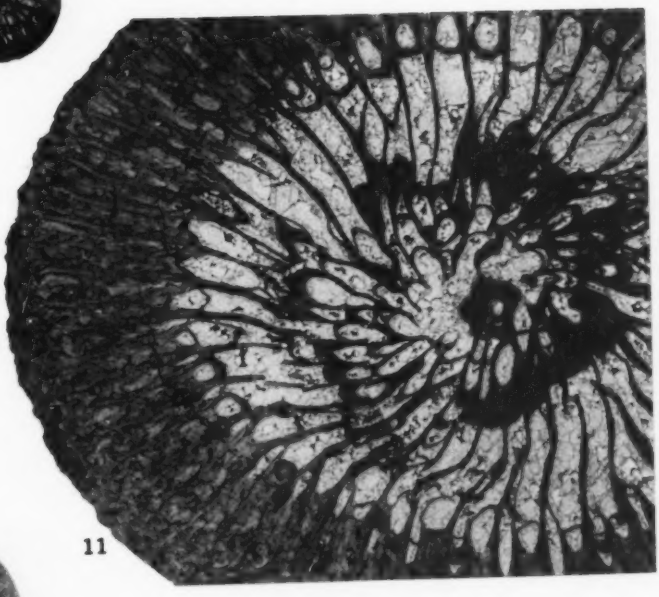
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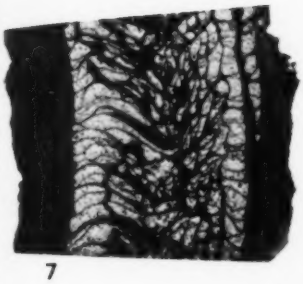
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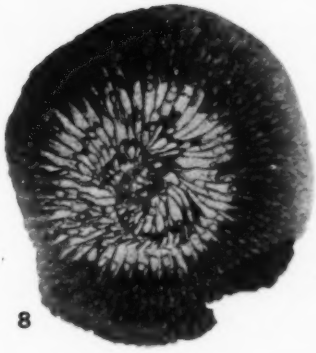
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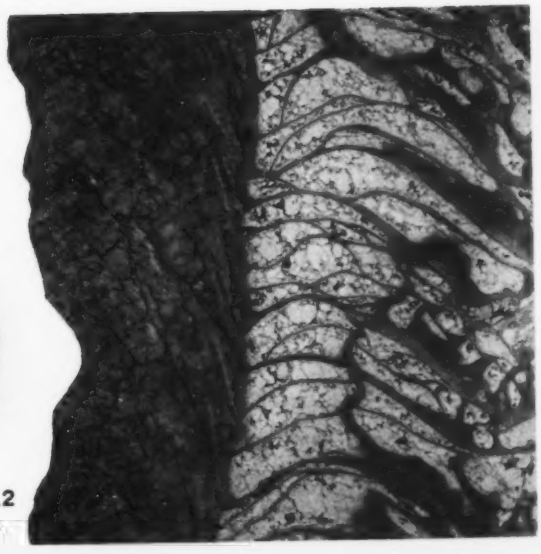
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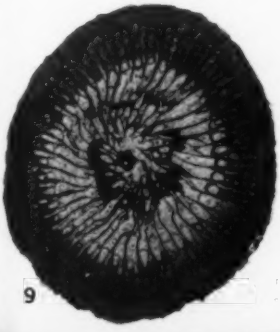
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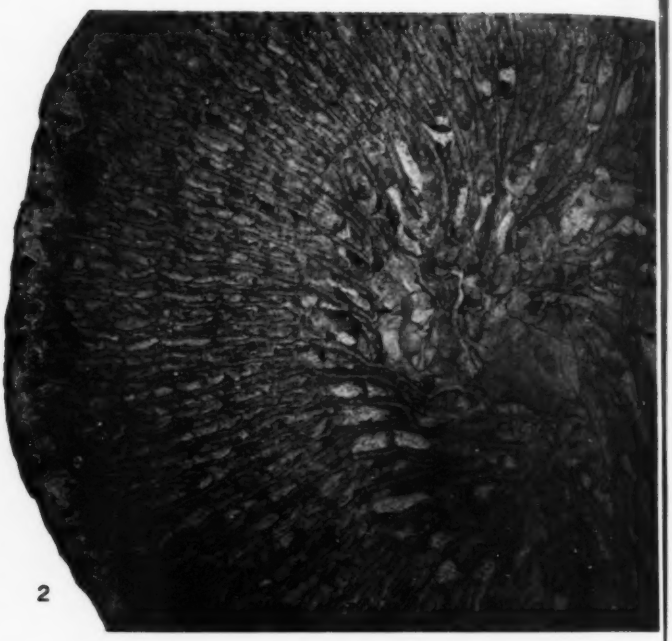

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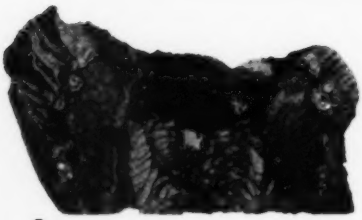

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lineage (*S. variabilis*) and quite stable in later members (Onondaga and Hamilton species). The "stability" of the later forms may be more apparent than real, however, as no studies based on adequate numbers of individuals have been reported. As a whole, the species that have previously been assigned to *Siphonophrentis* are most advanced in the amplexoid trend and in the development of a fossula with strongly downwarped tabulae.

Occurrence.—Reef facies of Coeymans limestone (Lower Devonian), Madison and Onondaga Counties, New York. Detailed locality data on table 8.

Material.—Holotype, USNM 137151; figured paratypes NYSM 11063–67 and USNM 137147–50; other measured specimens (unfigured paratypes) divided between the NYSM and USNM.

Genus BRIANTELASMA n. gen.

Type species.—*Briantelasma americanum* n. sp.

Horizon and locality of type species.—Reef facies of the Coeymans limestone of the Helderberg group, Lower Devonian, Madison and Oneida Counties, New York.

Diagnosis.—Simple, trochoid to cylindrical corals with major septa extending nearly to the axis, minor septa one-half this length and limited to the dissepimentarium. Dilated septa and additional deposits of stereoplasm entirely fill dissepimentarium; tabularium is partially or entirely filled especially in early growth stages. Tabulae strongly domed with axial depression, complete and closely spaced. Cardinal fossula present.

Remarks.—The genus is morphologically similar to *Briantia* Barrois, 1889, in the possession of a wide stereozone which in longitudinal section has a chevron or herringbone appearance apparently due to suppressed or incipient dissepiments. *Briantia* differs in the formation of the stereozone by septal dilation rather than by infilling as in *Briantelasma*. In addition *Briantia* lacks excess sterome in the tabularium and has simple, arched, incomplete and complete tabulae.

Briantelasma is similar in some respects to the Silurian *Pycnactis* Ryder, 1926. *Pycnactis* is completely filled with sterome due to septal dilation and tabulae are suppressed. According to the interpretations of Ryder (1926, p. 393–394) and subsequent workers (Lang and Smith, 1927, p. 471; Butler, 1937, p. 94) *Pycnactis* gave rise to *Phaulactis* Ryder, 1926, through decreased deposition of sterome starting at the periphery. Species of *Phaulactis* are filled with sterome in the lower part of the corallite but septal attenuation is characteristic of the ephebic dissepimentarium, and septal dilation is limited to the tabularium.

A different trend would be toward septal attenuation beginning at the axis. Serial sections of *Pycnactis* itself (Ryder, 1926, p. 387, 389, pl. IX, figs. 1–7) suggest that slight attenuation of septa at their axial ends characterized the latest stages of full grown forms. Acceleration of such a trend with resulting introduction of tabulae, would give rise to a form very much like *Briantelasma* but it is unlikely that *Briantelasma* is related to *Pycnactis* because of the different manner of stereoplasmic filling in the two genera.

In the tendency to less axial deposition of stereoplasm in later growth stages *Briantelasma* is similar to *Cymatelasma* Hill and Butler, 1936. The latter is characterized however by inverted conical (V-shaped) tabulae and by wavy septa and is clearly not closely allied to the present form.

BRIANTELASMA AMERICANUM n. sp.
Pl. 14, figs. 1–14

Diagnosis.—*Briantelasma* with tabularium filled with stereoplasm in neanic stage,

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EXPLANATION OF PLATE 16

All figures ×1 unless otherwise indicated

FIGS. *1–8*—*Pseudoblothrophyllum helderbergium*, n. gen., n. sp. *1,2*—Paratype, NYSM 11084, loc. 7; *1*, transverse section through mature part of corallum, *2*, portion of same (×3); *3*—Paratype, NYSM 11080, loc. 7; longitudinal section; *4*—Paratype, USNM 137164, loc. 9; exterior of nearly complete specimen; *5–7*—Paratype, USNM 137166, loc. 7; *5,6*—transverse sections through conical and cylindrical parts of comparatively slender corallum, *7*, portion of figure 6 (×3); *8*—Paratype, NYSM 11083, loc. 7; longitudinal section through calice of specimen showing series of abandoned, flaring calice rims.

partially filled in ephebic stage; marginarium wide.

External features.—Simple, small corals; trochoid to cylindrical with concave, convex, or stright sides in profile. Dimensions of apparently mature individuals: diameter at base of calice, 9–30 mm. average 18.6 mm.; length 2.5–4 cm. Smooth exterior and rounded calice rim very characteristic; occasional rounded rugae in some specimens are only external marking. Calice with moderately to gently sloping sides on the lower part of which the septa project as very low ridges; floor slightly concave, margined by shallow trench which corresponds to downbend of tabulae at edge of tabularium; septa project inward across the shallow trench but cannot be traced across the smooth floor. Cardinal fossula formed by downbending of the upper most tabula in a narrow zone on either side of the short cardinal septum; visible only at inner edge of marginal trench. Relatively large talon for support appears on a few individuals.

Internal features.—Major septa extend nearly to axis, number 24–40, average 33 in transverse section of average diameter. Minor septa limited to marginarium in which all septa are somewhat dilated and interseptal spaces are so filled with sterome as to form a solid mass of calcite through which individual septa can be traced with difficulty. Septa radially arranged although a slight pinnate tendency marks the position of the cardinal septum in many specimens; cardinal septum not otherwise differentiated in sections below the calice.

Tabularium diameter varies from one-third to three-quarters of total diameter, average one-half. Tabulae complete, gently concave axially, strongly bent down at margin of tabularium; irregularly spaced. Interior of corallum may be largely filled with stereoplasm especially in early growth stages; more commonly the stereoplasm is irregularly distributed in the mature tabularium. A chevron appearance of the marginarium is characteristic in longitudinal section.

Microstructure.—Septal structure moderately well preserved; appears similar to monacanthine type described by Hill (1936, p. 197,213; 1956, p. 234–236). Trabeculae appear as irregular dark spots forming discontinuous center line in transverse section; surrounding fibers pinnately arranged; septal boundaries well defined to obscure. In longitudinal section trabeculae appear as short blotchy rods arranged in growth rows which tend to parallel the distal edge of the septum. Lamellar interseptal stereoplasm is as described in section on general morphology. The stereoplasmic filling of the dissepimentarium is partly due to septal dilation and partly to deposition of lamellar stereoplasm in interseptal spaces.

Remarks.—The above description is based on 116 reasonably complete individuals from reefs of the Helderberg group in New York. The smooth exterior and rounded shape of this coral are sufficiently diagnostic that individuals can be picked from a collection with considerable accuracy. In longitudinal section the chevron appearance is characteristic. A few juveniles in the collection can be recognized by their small size, shape and structure which is like the neanic portion of adult coralla.

Individual variation within the species is extreme and some variation between collections from different reefs is noted, although such variation is insufficient to suggest geographic subspeciation. Variation in features which can be quantitatively analyzed is shown in table 2 and text-figures 5,6,14,-18,23–24 and 31. Shape variation is shown on text-figure 34.

Several extra large individuals are included within the species. These comprise 20 percent of the specimens assigned to this species from the Mosquito Point reef but are of minor importance in the other reef collections. These large individuals have an even smaller septal ratio than would be expected by the extension of the regression line based on "normal" individuals (text-fig. 18) but show such intergradation on the scatter diagrams (text-figs. 5,6,23 and 24) that it is impossible to separate them from the population as a whole. They are an additional indication of the variability of the group.

Occurrence.—Reef facies of the Coeymans limestone (Lower Devonian), Madison and Oneida Counties, New York. Limited to the eastern reef area. Detailed locality data in table 8.

Material.—Holotype, NYSM 11069; figured paratypes, USNM 137152–63 and NYSM 11068, 11070–79; other measured

specimens (unfigured paratypes) divided between the NYSM and USNM.

BRIANTELASMA KNOXBOROENSE n. sp.
Pl. 17, figs. 1–4

Diagnosis.—*Briantelasma* with wide tabularium not filled with stereoplasm, and smooth, featureless exterior.

External features.—Simple trochoid corals. Dimensions: Diameter of corallum at base of calice, 12–31 mm., average, 18 mm.; length, 2.5–4 cm. Exterior very smooth as in *B. americanum;* supporting talon present in some individuals. Calice known only in longitudinal section; rounded rim, steep sides, width greater than depth; floor concave axially with shallow marginal trench; nature of fossula in calice not known.

Internal features.—Major septa extend to axis or nearly so, number 30–36. Minor septa average one-third this length, limited to marginarium in which interseptal spaces are filled with stereoplasm. Septa slightly pinnate in arrangment. Tabularium diameter varies from .62–.74 of total diameter, averages .68. Tabulae strongly arched, axially concave; irregularly spaced, thin or thickened with stereoplasm. Tabularium more or less open. Microstructure as in *B. americanum.*

Remarks.—The above description is based on 10 complete and incomplete individuals from the Knoxboro reef. Two or 3 of the smaller specimens probably represent immature individuals, but the collection is too small to be certain of this. Variation within the 10 specimens is indicated on table 3 and text-figures 7, 25, and 32.

Twenty-one specimens of *B. americanum* were collected at the same locality. The two species are very similar in external appearance but can be distinguished on internal characters ("open" versus "closed" structure). Both show considerable variation and morphologic intermediates are known. Analysis of the total *Briantelasma* collected at Knoxboro showed tabularium ratio variation extending significantly above the limits of *B. americanum* as established by large collections from the Munnsville East and Mosquito Point reefs. In addition the Knoxboro collection showed a bimodal frequency distribution of tabularium ratios (text-fig. 32) with the point of division between the modes falling approximately at the upper limit of *B. americanum* as established by other collections. *B. knoxboroense* is thus separable from *B. americanum* on the basis of its "open" tabularium and high tabularium ratio.

Occurrence.—Reef facies of the Coeymans limestone, Lower Devonian, Oneida County, New York. Known only from the Knoxboro reef although 2 specimens from the Orchard reef and one from the Lenox reef (Madison County) are tentatively assigned to the species.

Material.—Holotype, USNM 137173; figured paratypes NYSM 11088 and USNM 137172. Other measured specimens (unfigured paratypes), NYSM 11089–92, and USNM 137174–76.

Genus PSEUDOBLOTHROPHYLLUM n. gen.

Type species.—*Pseudoblothrophyllum helderbergium* n. sp.

Horizon and locality of type species.—Reef facies of the Coeymans limestone, Helderberg group, Lower Devonian, Madison and Onondaga Counties, New York.

Diagnosis.—Simple, large, cylindrical corals with major septa extending nearly to the axis; minor septa limited to marginarium. Septal dilation and additional deposits of stereoplasm entirely fill marginarium which is very wide in ephebic stage, narrow in neanic stage. Cardinal fossula limited to tabularium, formed by short cardinal septum; septa slightly lonsdaloid in some forms. Tabulae complete; axially concave, periaxially arched, strongly bent downward at outer edge of tabularium. Exterior heavily annulated due to repeated calicinal rejuvenescence.

Remarks.—It is suggested that *Pseudoblothrophyllum* is the immediate ancestor of *Blothrophyllum* Billings, 1859, found in rocks of Onondaga and Hamilton age in eastern North America. The two genera are similar in the presence of 1) a broad lonsdaloid dissepimentarium (weakly developed in *Pseudoblothrophyllum*), 2) an annulated exterior due to repeated rejuvenescence, and 3) in many lesser details such as relative length of septa, and shape of tabulae. *Blothrophyllum* differs primarily in having a dissepimentarium with open dissepiments and in a stronger development of the lonsdaloid septal tendency.

Hill (1956, p. 256, 303) suggests that the

development of a lonsdaloid dissepimentarium from a septal stereozone is a recognizable trend in the Columnariina, to which she assigns *Blothrophyllum*. The suggested *Pseudoblothrophyllum-Blothrophyllum* lineage might represent a similar trend.

Pseudoblothrophyllum differs from *Kodonophyllum* and related genera of Silurian age, in lacking any axial structure formed by septa and in the presence of the lonsdaloid tendency. It differs from the chonophyllids in the presence of a well marked fossula and the absence of any well formed dissepiments. It differs from both of these groups in the formation of the marginarium by infilling rather than by septal dilation.

Pseudoblothrophyllum and *Briantelasma* with which it is associated in the reefs of the Coeymans limestone, are similar in some respects. They differ markedly in external appearance and in neanic internal structure. *Pseudoblothrophyllum* develops the wide marginarium during a late ontogenetic stage. In *Briantelasma* deposits of stereoplasm are present at all stages and are most extensive in the neanic stage. The two genera are not considered to be closely related.

PSEUDOBLOTHROPHYLLUM HELDERBERGIUM n. sp.

Pl. 15, figs. 1–12, pl. 16, figs. 1–8, pl. 17, figs. 16,17

Diagnosis.—Large, robust *Pseudoblothrophyllum* with wide marginarium and lonsdaleoid septal tendency.

External features.—Large, cylindrical corals; dimensions of apparently mature specimens: diameter, 27–51 mm., average 36.4 mm.; length of cylindrical portion, up to 10 cm.; length of expanding (conical) portion, 4–6 cm. Exterior gently to coarsely rugose; flaring abandoned calice rims spaced as closely as 3 mm. on some individuals, more widely spaced and subdued on others; longitudinal ornamentation consists of broad shallow septal grooves separated by more angulate ridges, giving a scalloped appearance in transverse section.

Calice wall vertical at bottom of calice, gradually assuming a gentle slope at the rim; calice wall corresponds to inner margin of septal stereozone and the diameter of the calice at its base equals that of the tabularium; calice floor conforms to shape of upper most tabula. Septa project as low ridges on sides and floor of calice; appearance of fossula in calice not known.

Internal features.—Transverse and longitudinal sections show sharply defined marginarium and tabularium, the latter occupying from four-tenths to three-quarters the diameter, average six-tenths. Major septa extend almost to the axis, more or less attenuate in tabularium where they are characteristically deflected in a counter-clockwise direction (seen from distal end). Minor septa limited to dissepimentarium where interseptal spaces are so filled with stereoplasm as to form a solid stereozone. Tangential sections of many individiduals show that septa are peripherially discontinuous (lonsdaloid tendency). Septa radially arranged; fossula formed by short cardinal septum. Major septa number 39–57; average 47 in section of 35 mm. diameter.

Tabulae complete; axially concave, periaxially convex, steeply descending to edge of tabularium; extremely variable in form; maximum relief on surface of tabula may exceed the radius of the tabularium or may be very subdued. Tabularium may be open except for the presence of the major septa and the tabulae or may be varyingly filled with stereoplasm; in some individuals the stereoplasm even forms an irregular axial structure, but a periaxial open zone is present in all specimen studied.

Neanic portions of individuals have a relatively narrow marginarium and open tabularium. There is a strong tendency for the tabularium diameter to remain relatively constant from the calyx to the conical part of the corallum; total diameter is more variable because of extreme rugosity and neanic tapering. This relationship is clearly expressed by the rapid increase in tabularium ratio as the apex of the coral is approached (text-fig. 29).

Several conical coralla in the collections apparently represent juveniles of this species. They are strikingly different at first glance because of their shape, narrow peripheral stereozone and "open" structure. They compare very well however with neanic portions of cylindrical individuals (text-figs. 30 and 32), and seem clearly to belong to this species.

Microstructure.—Septal structure well

preserved, conforms to general type described in section on morphology. Trabecular axes visible in most transverse sections as dark irregular center lines; septa sharply defined but become obscure near periphery. Lamellar tissue fills septal interspaces. Tangential sections of some individuals show discontinuity of septa in outer few mm. Where septa are tangentially continuous they show a pinch-and-swell structure which is considered to represent incipient discontinuity. Breaks or narrow points on peripheral edges of septa are at 2–3 mm. intervals corresponding to spacing of abandoned calice rims on exterior. Presumably the breaks or narrow points correspond to periods of contraction of the corallum as a whole.

Remarks.—The above description is based on over 100 individuals from the reef facies of the Coeymans limestone. Individual variation within the species is extreme but all reef "populations" vary within approximately the same limits. Variation in quantitatively analyzed features is shown in table 4 and figures 8,9,15,19,26–29, and 33. Most striking is the contrast between the overall pattern of adult individual variation in tabularium ratio with the ontogenetic pattern of the same feature. The regression line based on individual variation in adults is steeper than any of the lines based on serial sections of a single individual.

Other variables include 1) shape of tabulae, 2) degree of development of axial stereoplasmic deposits, 3) length of septa, 4) external appearance.

Tabula variation is largely in terms of the depth of the axial depression as shown on the plates.

Stereoplasmic deposits in the tabularium are virtually lacking in many individuals but quite extensively developed in others. Some individuals possess an apparent axial structure but in most specimens the deposits are irregularly scattered through the tabularium.

Variation in length of major septa is less important. In most individuals the major septa nearly reach the axis. In some however they are noticeably shorter and in one large individual the major septa extend only half way across the tabularium. Variation in length of minor septa is shown by the plots of tabularium diameter variation, as the length of the minor septa is approximated by the width of the marginarium.

Variation in external appearance is considerable. All individuals show periods of alternate increase and decrease in diameter (rejuvenescense). In some this is expressed by rather smooth annulations, but in most specimens the sharp edges of successive calicinal margins stand out in sharp relief.

Occurrence.—Reef facies of the Coeymans limestone (Lower Devonian) Madison and Onondaga Counties, New York. Especially abundant in central reef area. Detailed locality data in table 8.

Material.—Holotype, NYSM 11081; figured paratypes, USNM 137164–67, and NYSM 11080, 11082–84; measured specimens (unfigured paratypes) divided between USNM and NYSM.

PSEUDOBLOTHROPHYLLUM MUNNSVILLIUM n. sp.

Pl. 17, figs. 9–15

Diagnosis.—Small *Pseudoblothrophyllum* with relatively narrow marginarium (high tabularium ratio).

External features.—Simple, ceratoid and cylindrical corals. Dimensions of apparently mature individuals: diameter at base of calice 21–31 mm., average 25 mm.; length, 4 to 6 cm. Exterior marked by 3 or 4 coarse, irregularly spaced rugae, and by faint, longitudinal, septal grooves. Supporting talon present on some individuals. Calice known only in section: flaring, rounded rim, depth less than diameter at base; floor conforms to shape of tabulae with axial pit and peripheral trench; major septa cross trench and project as low ridges on wall of axial pit; fossula formed by short cardinal septum and slight downbending of tabulae near outer edge of raised portion.

Internal features.—Major septa extend to axis, number 34–46, average 40 in transverse section of average diameter. Minor septa limited to marginarium in which interseptal spaces are so filled with stereoplasm as to form a solid mass of calcite. Septa radially arranged except for slight pinnate tendency near cardinal septum. Microstructure similar to that of the other species in the genus. Septa are more or less sharply defined in marginarium with interseptal deposits clearly set off from the septa. Typically the interseptal deposits extend axially

along the sides of the septa for some distance, giving a thickened appearance to the septa in the outer part of the tabularium. Preservation is fair in most specimens.

Tabularium "open," diameter varies from one-half to three-fourths of total diameter, averages two-thirds. Tabulae strongly concave axially, periaxially arched, sharply bent down at margin of tabularium; closely but irregularly spaced, thin or thickened with stereoplasm.

Remarks.—The above description is based on 22 specimens, mostly from the Mosquito Point and Stockbridge South reefs. The geographic distribution of the species is the same as that of *P. helderbergium* but *P. munnsvillium* is never as common as the larger species. Variation within the species is shown on table 3, and on text-figures 7 and 25.

P. munnsvillium differs from the other species of *Pseudoblothrophyllum* here described by its high tabularium ratio and by the lack of abandoned calice rims.

Occurrence.—Reef facies of the Coeymans limestone, Lower Devonian, Madison County, New York. Detailed locality data on table 8.

Material.—Holotype, NYSM 11098; figured paratypes, NYSM 11097, and USNM 137181–82; other measured specimens (unfigured paratypes), USNM 137183–84, and NYSM 11099–11100.

PSEUDOBLOTHROPHYLLUM ARRECTUM n. sp.
Pl. 17, figs. 5–8

Diagnosis.—Small *Pseudoblothrophyllum* with a wide marginarium (low tabularium ratio) and a deep, erect calice.

External features.—Simple, ceratoid-cylindrical corals. Dimensions of apparently mature individuals: diameter at bottom of calice, 17–24 mm., average 20 mm.; length, 4–5 cm. Exterior apparently smooth; calicinal rejuvenescence at infrequent intervals gives 2 to 4 abandoned calice rims as the only external ornamentation. Supporting talon present on some individuals. Calice known only in longitudinal section; rounded rim; deep and steep sided, depth equal to or greater than diameter; floor conforms to shape of tabulae with gently concave axial region and marginal trench; nature of fossula in calice not known.

Internal features.—Major septa extend nearly to axis, number 30–37, average 33 in a transverse section of 20 mm. diameter. Minor septa limited to marginarium in which all interseptal spaces are so filled with stereoplasm as to form a solid mass of calcite Septa radially arranged, cardinal septum only weakly indicated by slight downbending of tabulae.

Tabularium diameter varies from four-tenths to two-thirds of total diameter, averages one-half. Tabulae complete, irregularly spaced; slightly concave axially, periaxially arched, bent down at margin of tabularium; thin or thickened with stereoplasm. Rest of tabularium open with only insignificant extra deposits except in earliest part of corallite where partial filling is noted.

Microstructure.—Transverse sections of only two specimens were studied but the structure is very similar to that described for *P. helderbergium*. One section shows the septa in direct lateral contact around most of the dissepimentarium with interseptal tissue on one side only; in the other, most of the septa are separated by lamellar stereoplasm. In two longitudinal sections the structure is as described for other species but preservation is poorer and the features less distinct.

Remarks.—The above description is based on 8 complete and incomplete individuals from a single collection (USGS 4629 SD) from the northern-most reef knob of the Mosquito Point reef. No specimens of the other species of *Pseudoblothrophyllum* were found on the same knob but the south end of the reef is one of the main localities for collecting *P. munnsvillium*. *P. heldergerbium* occurs on the reef but is uncommon (see table 8).

Little variation can be noted within the 8 specimens, probably because of the small size of the collection and the limited environmental conditions represented. Table 3 indicates the limited range in measured characters.

P. arrectum differs from *P. helderbergium* in its small size and from *P. munnsvillium* in its low tabularium ratio. It differs from both in its deep calice and in other lesser features.

In slightly eccentric longitudinal sections the septa appear as discontinuous lines extending up from the tabulae. This is interpreted as indicating a slight amplexoid

tendency not known in the other species of *Pseudoblothrophyllum* but is not considered to be of generic importance.

Occurrence.—Reef facies of the Coeymans limestone (Lower Devonian), Madison County, New York. Known only from the Mosquito Point reef.

Material.—Holotype, USNM 137178, figured paratypes, NYSM 11093 and USNM 137177; unfigured paratypes, USNM 137179–80, and NYSM 11094–96.

Genus FLETCHERINA Lang, Smith and Thomas, 1955

Cylindrophyllum Yabe and Hayasaka, 1915, p. 90–91, and 1920, p. 132–133; non Simpson, 1900.

Yabeia Lang, Smith and Thomas, 1940, p. 46, 140; Hill, 1942a, p. 239; non Resser and Endo, 1935.

Fletcherina Lang, Smith and Thomas, 1955, p. 261; Hill, 1956, p. 298.

Type species.—By monotypy, *Cylindrophyllum simplex* Yabe and Hayasaka, 1915, p. 91, 1920, p. 133–134, pl. vi, figs. 3a,b.

Horizon and locality of type species.—Devonian, Yunnan, China.

Diagnosis.—"Corallum composite, fasciculate; corallites long, erect, subparallel, only in contact at the point of gemmation; surface of the corallites transversely wrinkled and finely striated. No septa nor septal spines at all. Tabulae complete, moderately close, horizontal. Multiplied by lateral gemmation." (Yabe and Hayasaka, 1915, p. 90; 1920, p. 132).

Remarks.—This genus has been stated to differ from *Fletcheria* in the absence of any trace of septa, but according to Duncan (1956, explanation of pl. 25) *Fletcheria* may lack septa also. There are other significant differences, however. *Fletcheria* has thick walls and calicinal gemmation as opposed to the thin walls and lateral gemmation of *Fletcherina*. Examination of topotype material of *Fletcheria tubifera* (type species, sent to the USNM by Dr. Gerhard Regnéll Swedish Museum of Natural History) does not suggest any close relationship to *Fletcherina*.

FLETCHERINA INCOGNITA n. sp.
Pl. 18, fig. 9–13

Diagnosis.—*Fletcherina* with relatively wide-spaced tabulae and occasional marginal cysts formed by strong bending of tabulae or by dissepiments.

External features.—Phaceloid corallum, size unknown but presumably not large because individual corallites are weakly supported. Cylindrical corallites produced by lateral gemmation, attached only at point of gemmation; dimensions of corallites: diameter, 4–7 mm.; length of incomplete corallites, up to 3.8 cm. Exterior gently annulated; well preserved specimens show fine longitudinal grooves.

Internal features.—No trace of septa. Tabulae complete, horizontal or gently sagging except as noted below; very thin (1 mm) and spaced at 1.5 to 3 mm. intervals. Seven of 15 longitudinal sections show one to 5 narrow, overlapping "cysts" on one or both sides of the corallite; the outer wall of each "cyst" is the epitheca; the inner wall is formed in some cases by a separate unit, convex toward the axis of the coral (i.e. a dissepiment) but in other cases is formed by strong bending of the tabulae which are of an inverted hat-shape and strongly overlapping. Thickness of outer wall, .25–.3 mm. Calice unknown.

Remarks.—The above description is based on several corallites which were closely associated in the rock and which may represent a single corallum. Two examples of lateral gemmation are visible but the relation of most of the corallites cannot be determined.

The species is similar to *F. salmoni* (Hill) (1942a, p. 239–240, pl. VI, figs. 3,4), from the upper Middle Devonian of northern Queensland, Australia. Measurements and observed characters are almost identical but the "cysts" are lacking in the Australian species. The type species, *F. simplex* (Yabe and Hazasaka), 1915, from the Devonian of Yunnan, China, also lacks "cysts" but differs from both *F. salmoni* and *F. incognita* in having very flat, regularly close-spaced tabulae.

The presence of "cysts" in *F. incognita* is not a constant character, but they were found in approximately half of the sectioned corallites and must be considered diagnostic of the species.

Occurrence.—Reef facies of Coeymans limestone (Lower Devonian), Madison County, New York. Known only from the Stockbridge North reef of the central reef area.

Material.—Holotype, NYSM 11108; sections from holotype, USNM 137191.

Genus TRYPLASMA Lonsdale, 1845

Tryplasma Lonsdale, 1845, p. 613; Etheridge, 1907, p. 76–77; Hill, 1936, p. 204–206; 1940, p. 405; Schouppé, 1950, p. 80–84; Wang, 1950, p. 226; Stumm, 1952, p. 842; Hill, 1956, p. 312.
Pholidophyllum Lindström, 1871, p. 125.
Spiniferina Penecke, 1894, p. 592.
Stortophyllum Wedekind, 1927, p. 30,31.

Type species.—By subsequent designation of Etheridge, 1907, p. 42, *Tryplasma aequabile* Lonsdale, 1845, p. 613–614, 633, pl. A, figs. 7,7a.

Horizon and locality of type species.—Silurian, northern Urals, U.S.S.R.

Diagnosis.—Solitary, dendroid, or phaceloid corals with spinose (acanthine) septa and narrow septal stereozone. Tabulae usually complete; no dissepiments.

Remarks.—See Etheridge (1907), Hill (1936, 1940, and 1956), and Schouppé (1950) for more extensive discussions and synonomies.

Species of *Tryplasma* are most common in rocks of Silurian age but Devonian species have previously been described from Europe (Penecke, 1894, p. 592, Austria; Soshkina, 1937, 1949, 1952, Eastern Urals) and Australia (Etheridge, 1907; Hill and Jones, 1940, Hill, 1942b and c). The following description extends the range of Lower Devonian *Tryplasma* to eastern North America.

TRYPLASMA FASCICULARIUM n. sp.
Pl. 19, figs. 1–12

Diagnosis.—Phaceloid *Tryplasma* with strongly concave tabulae, long major septa, and rudimentary minor septa.

External features.—Phaceloid coralla composed of cylindrical corallites. Dimensions of corallites as follows: diameter of cylindrical portion, 3–8 mm., average 4.8 mm.; length between gemmation stages, up to 4 cm. Exterior very gently rugose, marked by fine, close-spaced encircling and longitudinal striae. Calice very deep, with almost vertical sides and concave bottom; appearance of septa in calice not known.

No complete colonies have been collected but coralla or portions of coralla with thicknesses and diameters of several inches to a foot or more were observed in the field. Calicinal increase is 2-, 3-, 4- or 5-fold. Spacing of corallites varies; individuals are in lateral contact or separated by any distance up to one corallite diameter. Infrequent lateral processes are the only means of support in addition to basal attachment at points of gemmation and lateral contact without structural modification.

Internal features.—Septa acanthine with spines directed inward and upward; major septa may extend nearly to axis or only half that distance, number 17 to 28 in corallites of average diameter. Septal stereozone, .5–1.5 mm. wide; minor septa short, competely buried in stereozone in subcalice transverse sections, but some can be seen in most calice sections. Tabulae complete, thin, gently to strongly concave, frequently pierced by septal spines which may intersect nearly at right angles to the tabulae.

Microstructure.—Septa are monacanthine (Hill, 1936, p. 213–214), each septal spine

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EXPLANATION OF PLATE 17

FIGS. *1–4—Briantelasma knoxboroense*, n. sp. (all ×1½). *1,2*—Holotype, USNM 137173, loc. 3; lower and upper transverse sections similarly oriented; *3*—Paratype, USNM 137172, loc. 3; longitudinal section; *4*—Paratype, NYSM 11088, loc. 3; transverse section of small individual.

5–8—Pseudoblothrophyllum arrectum, n. sp. (all ×1½). *5,6*—Holotype, USNM 137178, loc. 4; *5*, longitudinal section *6*, transverse section; *7*—Paratype, NYSM 11093, loc. 4; transverse section; *8*—Paratype, USNM 137177, loc. 4, longitudinal section of specimen encrusted by a stromatoporoid.

9–15—Pseudoblothrophyllum munnsvillium, n. sp. (×1, except as indicated). *9,10*—Paratype, USNM 137182, loc. 8; lower and upper transverse sections similarly oriented; *11*—Paratype, USNM 137181, loc. 4; longitudinal section; *12–14*—Holotype, NYSM 11098, loc. 7; *12,13*, lower and upper transverse sections similarly oriented, *13* intersects the base of the calice and shows axial pit, periaxial tabular arch, and cardinal fossula; *14*, portion of fig. *12* (×6.7). *15*—Paratype, NYSM 11097, loc. 4; longitudinal section.

16,17—Pseudoblothrophyllum helderbergium, n. sp. Paratype, USNM 137165, loc. 4; *16*, longitudinal section through calice, *17*, longitudinal section of marginarium through single septum (×3).

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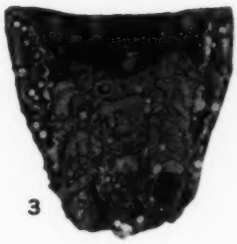
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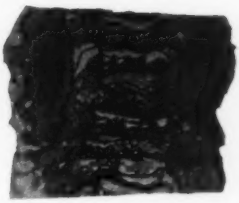
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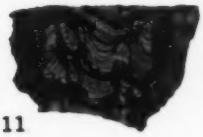
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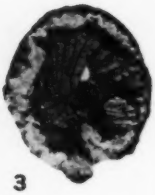

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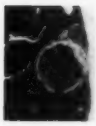

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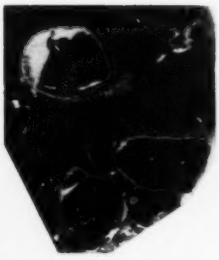

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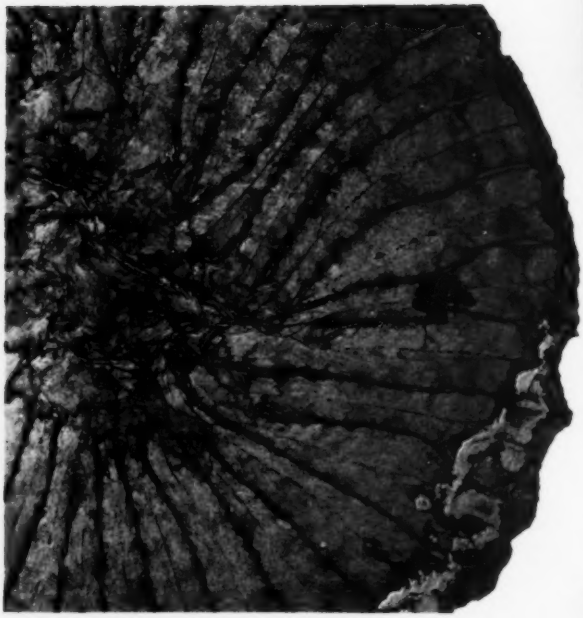

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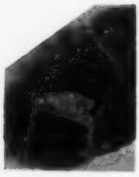

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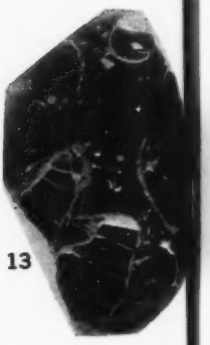

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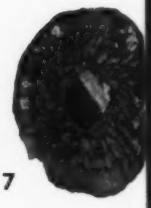

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being formed by a single monacanth trabecula. Stereozone formed by vertical and horizontal dilation of monacanths. Tabulae appear to be formed by lamellar tissue but no other lamellar structures have been noted in this species.

Remarks.—The above description is based on several hundred individuals in some 20 coralla or portions of coralla. Thin or polished sections of most of these were studied to obtain qualitative data but measurements are primarily based on 160 individuals of 8 coralla from 5 of the reefs. *T. fasciculariurn* is the only common colonial rugose coral known from rocks of Helderberg age in New York and is easily recognized in the field by its gross characters.

Variation within and between coralla is considerable. Variation in diameter of cylindrical portion of corallites, number of major septa and septal ratio is shown in table 5 and text-figures 10–12 16 and 20. Variation in length of major septa and in concavity of tabulae is as extreme. Within individual corallites there is considerable variation in tabula shape, but number and length of septa and diameter are more constant.

T. fasciculariurn can be distinguished from most previously described species of *Tryplasma* by the presence of strongly concave tabulae.

Several Silurian species are known with moderately to strongly concave tabulae but they differ in being solitary and in having relatively short septa. *Stortophyllum* Wedekind was established on forms of this type but is considered to be synonomous with *Tryplasma* (Stumm, 1952, p. 842; Hill, 1956, p. 312).

Previously described Devonian species have flat tabulae except for *T. devonica* (Penecke) 1894 from Austria. Illustrations of this solitary species show moderately concave tuabulae, but very short septa and a relatively wide septal stereozone.

Occurrence.—Reef facies of the Coeymans limestone (Lower Devonian), Madison and Oneida Counties, New York. Present or common on all reefs studied. A single corallum collected from the non-reef facies of the same formation in Oneida County (loc. 2; USGS 4653–SD) is referred to the same species. The specimen is poorly preserved but similar in all important details. Detailed locality data in table 8.

Material.—Holotype, USNM 137192 (sections from holotype, NYSM 11112); figured paratypes, NYSM 11109–11; other measured specimens (unfigured paratypes), NSYM 11113–17, USNM 137193–95.

Genus Aknisophyllum n. gen.

Type species.—*Aknisophyllum consuitum* n. sp.

Horizon and locality of type species.—Non-reef facies of the Coeymans limestone, Helderberg group, Lower Devonian; Oneida and Herkimer Counties, New York.

Diagnosis.—Simple trochoid corals with very attenuate major septa reaching the axis only in neanic portions of corallum; minor septa rudimentary. Interior of corallum entirely filled with stereoplasm except at base of V-shaped calice where one flat tabula may be separated from the other deposits. Cardinal fossula usually present.

Remarks.—This genus differs from *Briantelasma* in the short, sharply defined, attenuate major septa; in the general lack of

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Explanation of Plate 18

Figures ×1½ unless otherwise indicated

Figs. *1–8*—*Aknisophyllum consuitum*, n. gen., n. sp. *1–5*—Holotype, USNM 137185, loc. 1; *1–3*, serial transverse sections showing relatively longer septa in earlier stages and completely filled interior; *4–5*, enlarged portions of figs. *2* and *1* respectively (×6.7), note that septa are extremely attenuate and that interseptal deposits are many times as thick; *6*—Paratype, NYSM 11101, loc. 1; longitudinal section of beekitized individual to show shape; *7–8*—Paratype, NYSM 11102, loc. 2; *7*, transverse section through lower part of V-shaped calice; *8*, portion of higher transverse section showing normally attenuate cardinal septum without adjacent interseptal deposits (×6.7).

9–13—*Fletcherina incognita*, n. sp., all specimens considered to be from single corallum, holotype NYSM 11108 (USNM 137191), loc. 7. *9*—Transverse section of small corallite; *10*—Transverse and oblique sections, note encrusting stromatoporoid; *11*—Longitudinal section (×4), showing cysts along part of length; *12*—Longitudinal section of corallite with cysts; *13*—One transverse and two longitudinal sections (without cysts), all partly oblique.

distinct horizontal structures; and in the complete filling of the interior by stereoplasm. It differs from Pycnactis Ryder, 1926, in that the filling of the corallum is by infilling rather than by dilation of the septa.

AKNISOPHYLLUM CONSUITUM n. sp.
Pl. 18, figs. 1–8

Diagnosis.—As for genus.

External features.—Simple, small, curved or straight trochoid corals. Dimensions of apparently mature individuals: diameter at base of calice, 14–19 mm.; maximum length, 2.5–4 cm. Exterior smooth except for a few growth undulations; very fine septal grooves may be present. Calice deep, V-shaped, angle at base 90° or less; septa project on sides as low, sharp-crested ridges. Fossula faintly marked to moderate strong in calices of different individuals; where well developed it is formed by non-deposition of interseptal stereoplasm on either side of attenuate cardinal septum; located on concave side of corallum.

Internal features.—Major septa very attenuate, arranged with only slight pinnate tendency, number 38–42; septal length varies in a given transverse section from .5 to .75 or the full distance to the axis, giving an eccentric appearance to many sections. Minor septa very short, apparently lacking in some cases. Wide interseptal spaces and axial region filled with stereoplasm. A single flat, horizontal tabula may be present at base of calice, but some individuals show no distinct horizontal structures.

Transverse sections through neanic portion of corallum show major septa extending nearly to axis; similar to ephebic sections in other respects.

Microstructure.—Septa very narrow with indistinct structure; boundaries sharply defined except at inner end where septa thicken and grade into axial stereoplasm. Near the periphery, secondary lamellar stereoplasm tends to wrap around the minor septa forming a series of curves which are axially convex and concave on the septal and interseptal radii respectively. Periaxially and axially the structure is less distinct. Between major septa the interseptal stereoplasm is divided by a distinct center-line on either side of which the orientation of laminae varies, perhaps due to recrystallization. Interseptal stereoplasm grades imperceptively into the axial deposits.

Remarks.—The above description is based on 13 complete and incomplete individuals from 2 non-reef exposures of the Coeymans limestone in New York. The short, stubby shape of most of the specimens is quite different from that of associated corals. Individual variation is mainly in terms of length of major septa, eccentricness of septal development, and presence or absence of distinct tabulae. In none of these features is variation extreme, possibly because of the small sample. Size and septal ratio variation are shown on table 6.

Occurrence.—Non-reef facies of the Coeymans limestone (Lower Devonian), Oneida and Herkimer Counties, New York. Localities 1 and 2 (USGS 4603 and 4653 SD).

Material.—Holotype, USNM 137185; figured paratypes, NYSM 11101–02; unfigured paratypes, USNM 137186–90, NYSM 11103–07.

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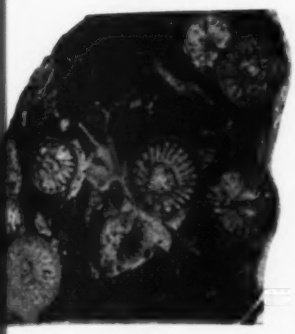
EXPLANATION OF PLATE 19

FIGS. *1–12—Tryplasma fascicularium*, n. sp. *1–4*—Paratype, NYSM 11109 (colony 2), loc. 5; serial transverse sections (lower to upper, all ×2), lower left corallite divided between sections *2* and *3*, note that division is 5-fold and that left individual in group is an innocent bystander; calicinal division in large corallite near center starts in fig. *2* and is completed in fig. *3*, note adherence of some individuals to others by lateral growths; *5*—Paratype, NYSM 11110 (colony 9), loc. 4; transverse section through calice of single individual to show minor septa (×4); *6–7*—NYSM 11111 (colony 4), loc. 4; longitudinal sections of corallites (×2), *6* shows deep calice, both show concave tabulae and acanthine septa; *8–12*—Holotype, USNM 137192 (NYSM 11112) (colony 3), loc. 4; *8–10*, lower to upper serial sections (×1½) of portion of corallum, note 5-fold axial increase in left center corallite and beginning of division in upper right corallite (fig. *10*); *11,12*, longitudinal sections, *11* shows axial increase (×1½), *12* (×2), both show tabulae and acanthine septa.



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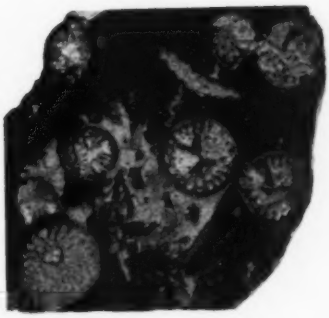

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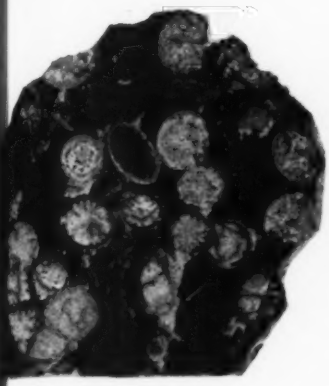

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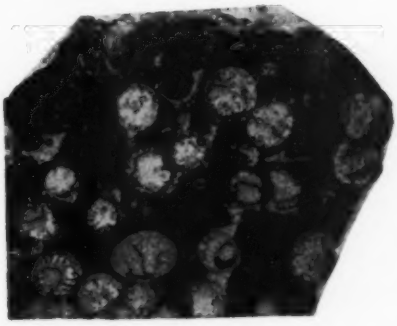

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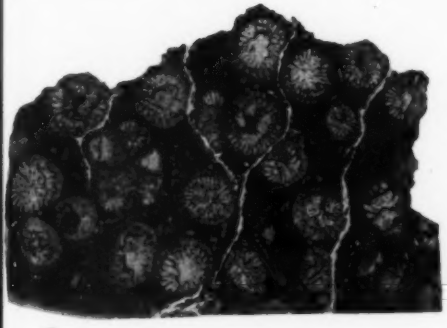

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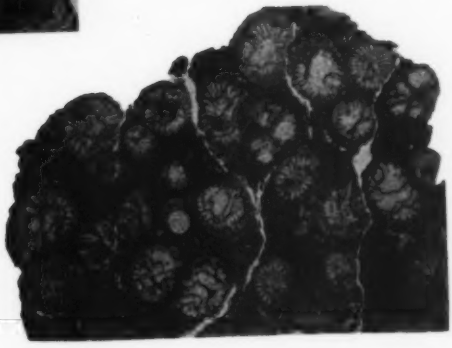

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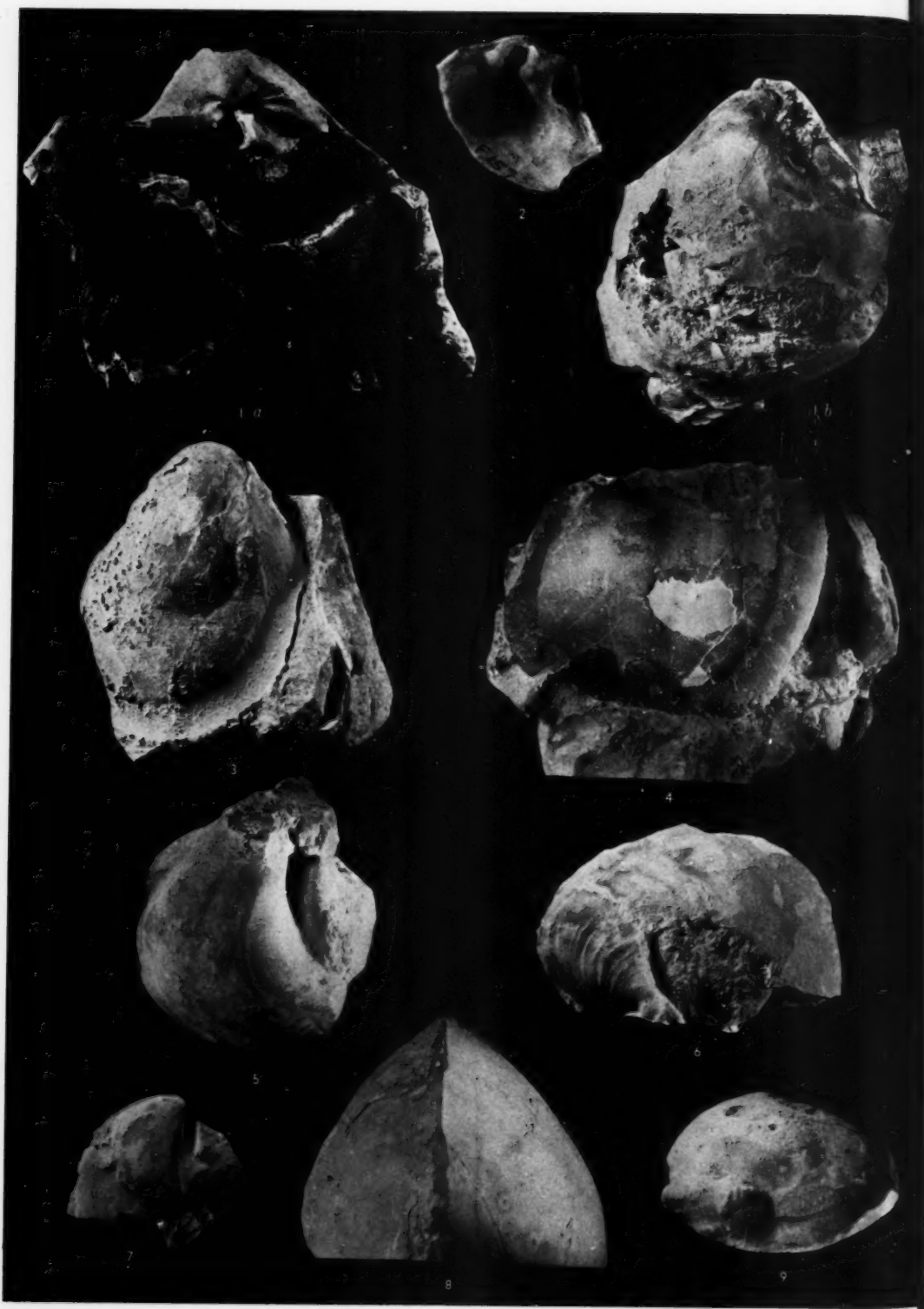
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JOURNAL OF PALEONTOLOGY, V. 34, NO. 1, P. 101–106, PL. 20, 4 TEXT-FIGS., JANUARY, 1960

A NEW SPECIES OF THE PELECYPOD *MEGALODON* FROM THE PERMO-CARBONIFEROUS OF THE BANFF AREA, ALBERTA

A. McGUGAN
Calgary, Alberta

ABSTRACT—A pelecypod from Exshaw Creek, Banff, Alberta is referable to the genus *Megalodon* Sowerby and is given the new specific name *M. banffensis*. Although common in Europe, *Megalodon* is rare in North America and has not been previously recorded from western Canada.

INTRODUCTION

IN THE summer of 1958 a reconnaissance of the Permo-Carboniferous interval in the Banff area resulted in the discovery of a number of specimens of a unusual pelecypod. These were collected from a river cliff in Exshaw Creek (text-fig. 1) in strata high in the Rocky Mountain formation (the usage of the term "Rocky Mountain formation" in this paper is that of the A.A.P.G./ASPG Carboniferous Committee, 1955.)

On further investigation, no previous record of the above pelecypod could be found in any published literature. It was eventually decided that the new species should be referred to the genus *Megaladon* which is rather common in the Devonian and Triassic of Europe and the Middle East, although extremely rare in North America.

The author gratefully acknowledges the helpful assistance of Dr A. V. Carozzi (University of Illinois), Miss J. E. Rapson (Shell Oil Co. of Canada Ltd.) and Mr. B. Tomljanovic (Pacific Petroleums Ltd.) in the field. Miss Rapson also checked the petrographic classification of the samples. Dr. N. D. Newell (American Museum of Natural History) kindly confirmed the identification of *Megalodon*, prepared one of the hingelines, and offered much helpful advice. Dr. E. L. Yochelson (U. S. National Museum) examined the material and confirmed the identification of *Plagioglypta*. Dr. L. R. Cox (British Museum of Natural History) kindly gave advice on European references. At the time of the discovery the author was receiving financial assistance towards field expenses from Queen's University Scientific Research funds.

STRATIGRAPHY

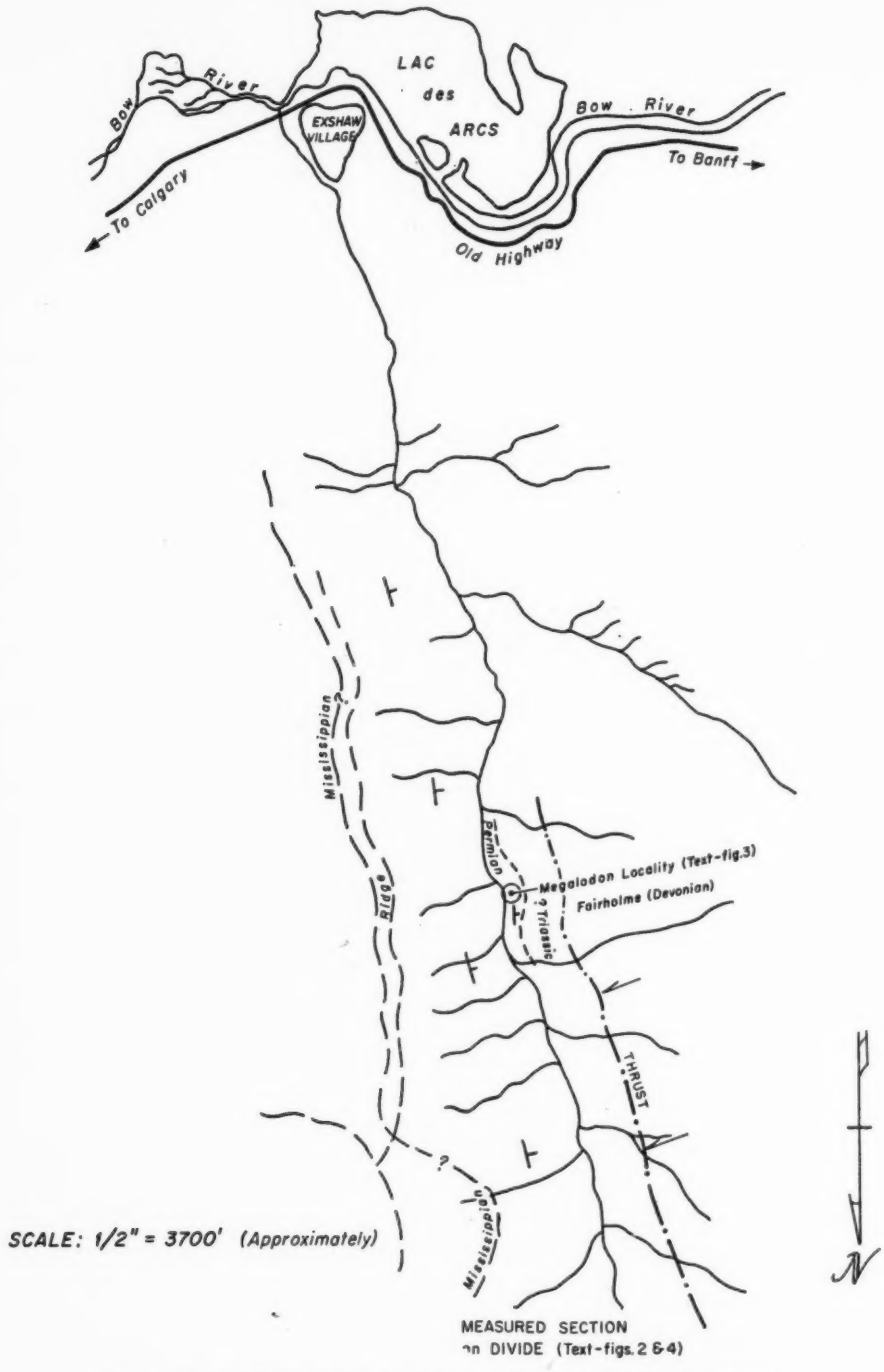
The stratigraphic succession of the higher part of the Permo-Carboniferous interval is illustrated in text-fig. 2. This is based on the excellent exposures on the divide north of the headwaters of Exshaw Creek illustrated by text-fig. 4.

THE EXSHAW *Megalodon* BEDS

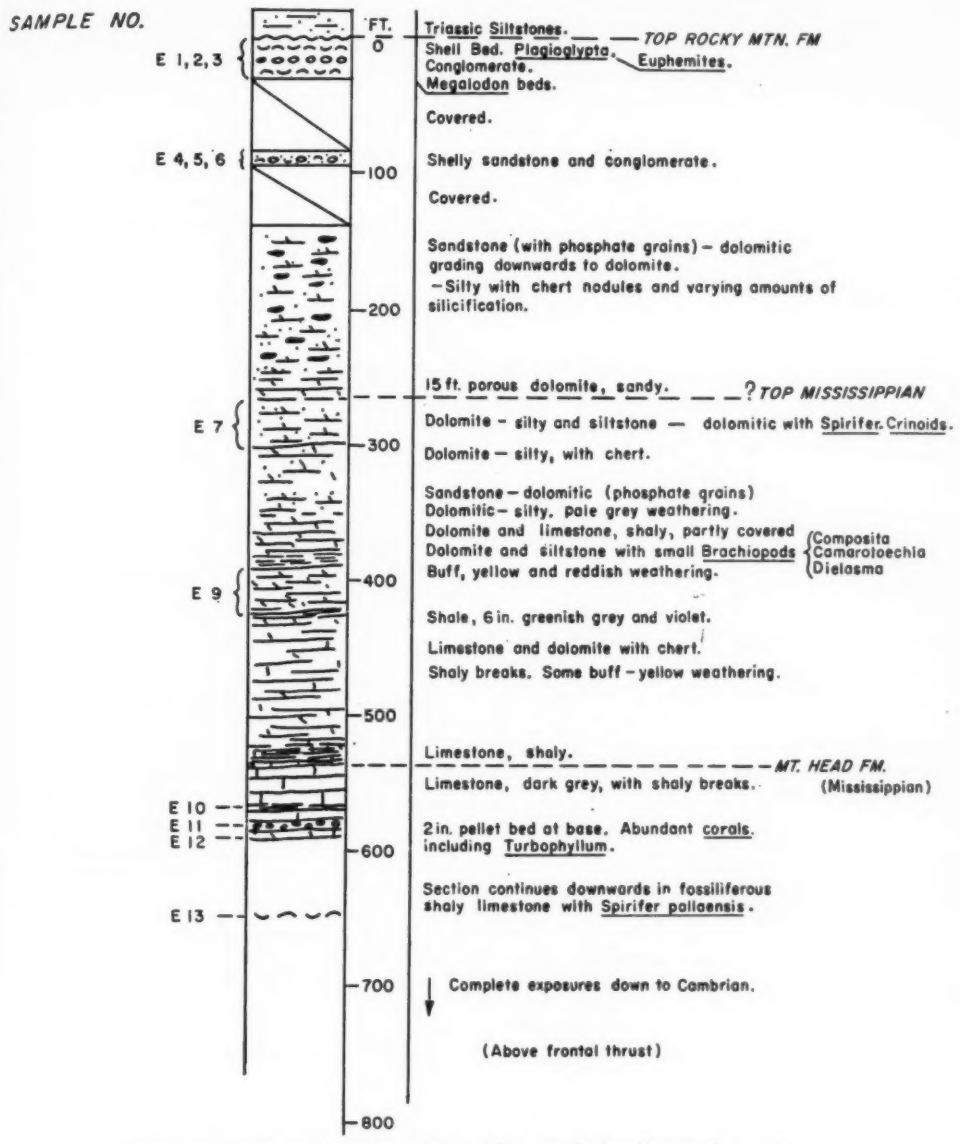
As may be seen from the detailed section (text-fig. 3) these beds consist mainly of more or less silicified dolomite with a considerable amount of bedded and nodular chert. This results in an extremely hard rock, from which it is difficult to obtain good fossil specimens. Those figured and described here were obtained either from weathered surfaces, or from shattered por-

EXPLANATION OF PLATE 20

FIG. *1–9*—Megalodon banffensis n. sp. *1*—(a) Interior, right valve showing hinge teeth, ×1. Miller Hall F157 (i). (b) Internal cast, same specimen, showing anterior buttress. ×¾. Miller Hall F157 (ii). *2*—Interior, left valve, young specimen, showing hinge teeth and anterior buttress. ×1. Miller Hall F157 (iii). *3*—Internal cast, left valve, showing posterior adductor impression and peripheral flange. ×¾. Miller Hall F157 (iv). *4*—Shell interior, showing posterior adductor impression and peripheral flange. ×¾. Miller Hall F157 (v). *5*—Internal cast, right valve, showing buttress cavity and radial ridges. ×¾. Miller Hall F157 (vi). *6*—Portion of shell exterior, showing concentric ornament. ×¾. Miller Hall F157 (vii). *7*—Internal cast, right valve, young specimen, showing buttress cavity and position of anterior adductor. ×1¼ Miller Hall F157 (viii). *8*—Internal cast, showing ventral margin. ×¾. Miller Hall F157 (ix). *9*—Internal cast, showing posterior muscle scar. ×1. Miller Hall F157 (x).



TEXT-FIG. *1*—Map showing areal geology in vicinity of Exshaw Creek.



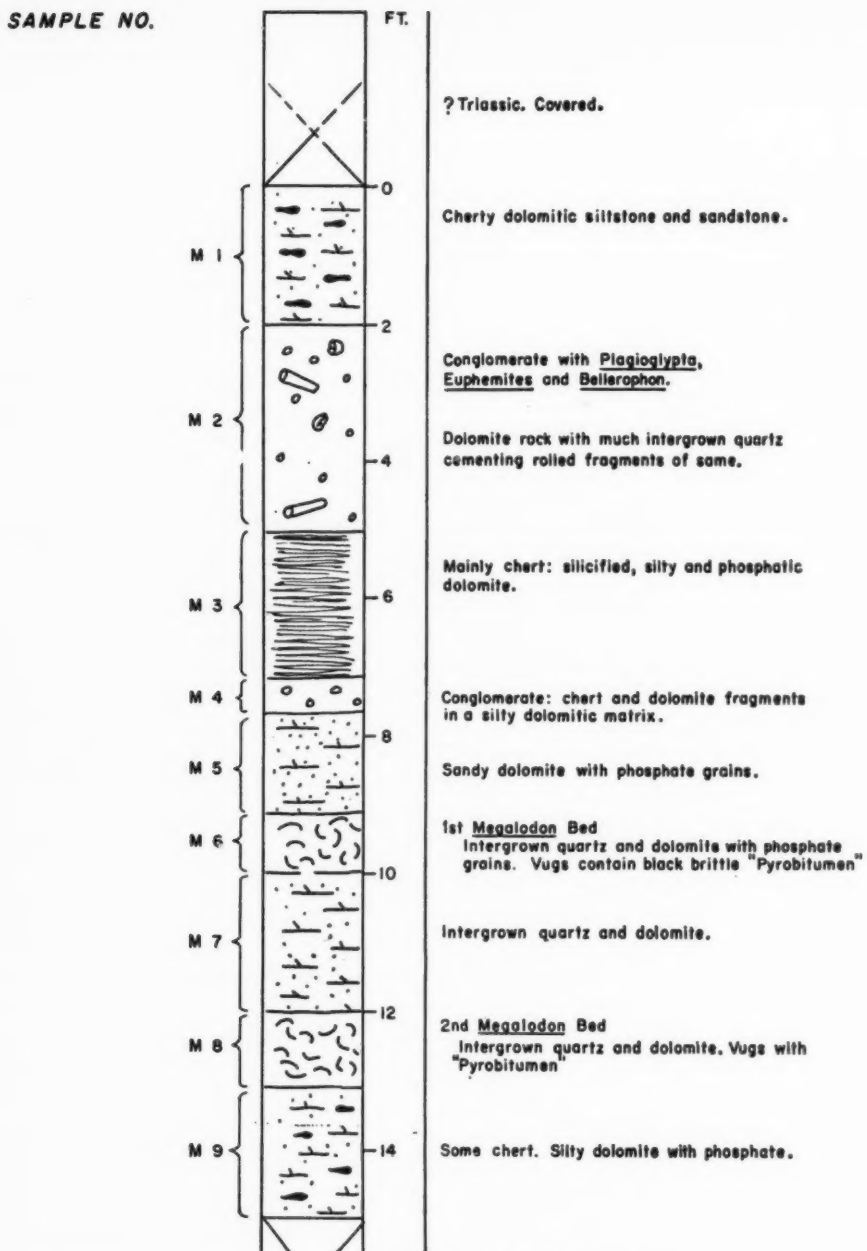
TEXT-FIG. 2—Stratigraphic section of Permo-Carboniferous Succession at headwaters of Exshaw Creek.

tions of the outcrop, or, since the shells are silicified, in the laboratory by treatment with concentrated hydrochloric acid.

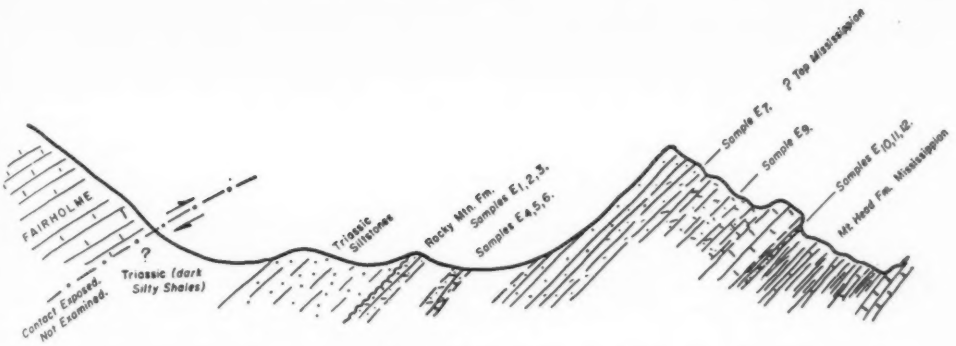
After acid treatment, microscopic examination of the disintegrated matrix revealed a silicified microfauna of smooth ostracods, high-spired gastropods, young pelecypods and a great abundance of sponge spicules and shell debris. Small undetermined corals also occur very rarely.

Approximately 40 pelecypod specimens were collected including the nine syntypes illustrated in plate 20.

Dr. P. S. Warren (University of Alberta)



TEXT-FIG. 3—Detailed stratigraphic section of *Megalodon* beds at Exshaw Creek.



TEXT-FIG. 4—Structural section of Carboniferous and Triassic rocks at the headwaters of Exshaw Creek, looking north.

in a written communication, states that the above pelecypod has also been found "from Tunnel Mountain above the unconformity, and so . . . (is) . . . undoubtedly Permian in age."

The association of *Plagioglypta* cf. *canna* (White) and *Euphemites* cf. *carbonarius arenarius* (Shimer) with the Exshaw pelecypod beds provides further confirmation of this age diagnosis. (However, in a recent personal communication, Dr. Yochelson states that at least some of the specimens of "*Euphemites*" are, in fact, probably *Bellerophon.*)

Fusulinids and other fossils recently discovered in associated beds have a strongly Pennsylvanian aspect.

SYSTEMATIC PALEONTOLOGY

Family MEGALODONTIDAE Zittel
Genus MEGALODON Sowerby 1827
MEGALODON BANFFENSIS, n. sp.
Pl. 20, figs. 1–9

Shell heavy, adults up to 3 inches long, 2 inches high, and 2½ inches in thickness across two articulated valves; beaks prosogyre; hinge line massive, fairly straight, hinge plate broad; right valve with a sharp, blade-shaped cardinal tooth flanked by two deep rounded sockets. One minor posterior lateral tooth. (fig. 1a). Left valve with two large rounded cardinal teeth separated by a deep socket. (fig. 2). The shell is infolded dorsally in two places to merge with the massive hinge structures. The anterior infold forms a conspicuous buttress (figs. 1b,-2,5). The postero-dorsal infold is also strong but less conspicuous. Shell anisomyarian, posterior adductor scar more prominent (fig. 9), situated close to the pallial line which is represented by a peripheral flange, (figs. 3,4). Anterior adductor scar less conspicuous, situated immediately anterior to the ventral extremity of the anterior buttress (fig. 7). The posterior adductor scar sometimes occurs flanking a slight radial ridge, and other irregular radial ridges may be present (fig. 5). External surface of shell with concentric ornament (fig. 6).

Types.—Miller Hall, Queen's University, Kingston. 9 syntypes, Catalogue F157. (i)-(ix).

RELATION OF PRESENT GROUP TO RECORDED DEVONIAN AND TRIASSIC REPRESENTATIVES

Careful examination of the literature cited in the bibliography of the present paper failed to reveal any published "*Megalodon*" closely resembling that reported here. Neither could any definite conclusions be reached regarding the relationships of Devonian and Triassic forms referred to this genus. It is not established that European Devonian and Triassic "*Megalodon*" are actually congenetic. Neither is it certain that the present collection may be correctly referred to either of the above groups. Further work on the family is therefore necessary.

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MANUSCRIPT RECEIVED FEBRUARY 26, 1959.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 1, P. 107–126, PLS. 21–25, 3 TEXT-FIGS., JANUARY, 1960

MISSISSIPPIAN LITHOSTROTIONID ZONES OF THE SOUTHERN CANADIAN ROCKY MOUNTAINS[1]

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ABSTRACT—Lithostrotionid species of the Banff, Livingstone, Mount Head and Etherington formations of the southern Canadian Rocky Mountains are described and arranged according to zones. In ascending order zonation is: the *Lithostrotionella jasperensis* zone of the upper part of the middle member; and the *Lithostrotionella micra* and *Lithostrotion mutabile* zones of the upper member of the Banff (Shunda); the *Lithostrotion sinuosum* zone of upper Livingstone; the *Lithostrotionella bailliei* n. sp. and *L. astraeiformis* zones of lower Mount Head, the *Lithostrotion whitneyi* zone of middle and upper Mount Head; the *L. arizelum* zone of uppermost Mount Head; the *L. genevievensis* zone of lower Etherington; and the *Lithostrotionella stelcki* n. sp. zone of upper Etherington.

INTRODUCTION

MISSISSIPPIAN *Lithostrotion* and *Lithostrotionella*, herein described and zoned, occur in the Banff formation and Rundle group of the southern Canadian Rocky Mountains, between North Saskatchewan River and the International Boundary. Text-figure 1 shows fossil localities and areas referred to in text.

The Banff and Rundle comprise a respectively argillaceous and calcareous sequence aggregating between 3500 and 4000 feet in their thicker portions. The sequence is underlain by black shales of the Devonian (?) Exshaw formation and overlain by Permo-Carboniferous clastics of the Tunnel Mountain formation and Rocky Mountain group. Both the Banff and Rundle vary considerably in thickness and lithology. This has resulted in varied interpretations for both stratigraphic divisions and age relationships. The reader is referred to Moore (1958) for history of nomenclature.

The Banff formation at the type section (Kindle, 1924) on Mount Rundle, near Banff, Alberta, is a 1500 foot argillaceous sequence divisible into three members (Warren, 1927; Beales, 1950; Moore, 1958): a lower calcareous shale; a middle interbedded shale and limestone; and an upper argillaceous limestone (see text-fig. 2). The lower and middle members are Kinderhookian, and the upper member is probably lower Osagean in age. South from the Banff area this three-fold lithologic division is replaced by a monotonous sequence of unfossiliferous cherty argillaceous dolomites. Faunal evidence from the overlying Rundle at Crowsnest Pass (Nelson, 1959) suggests that the upper beds of this Banff sequence may be approximately the same age as those at the type section. Age of the lower beds, however, is not accurately known. North from the Banff area four lithologic divisions are present in the Banff formation (see text-fig. 3). The lower part of the upper member changes to a light-colored crinoidal limestone. This limestone has been called the Pekisko formation (not type) by Stearn (1956), Penner (1958a), Brady (1958), et al., and has been designated in this area as the basal unit of the Rundle (Stearn, ibid.; Brady, ibid.; Penner, ibid.; Brown, 1952; Kelly, 1942). The overlying lateral and lithologic equivalents of type Upper Banff are the type Shunda formation (Stearn, 1956). In the opinion of the present writer the base of the Rundle in the area north of Banff should be raised to include strata immediately above the Shunda and thus be laterally or diachronically related to type Rundle (see also Moore, 1958).

The Rundle group comprises between 2000 and 3500 feet of resistant, generally light-colored, calcareous strata ranging in age from Osagean to Chesterian. The group was first defined as a formation by Kindle (1924) with its type section on Mount Rundle, Banff, Alberta. Beales (1950) later

[1] Cost of publication borne by the Geological Society of America.

designated the more complete section on nearby Tunnel Mountain as the type. Rules of stratigraphic nomenclature may prevent Beales' designation from being accepted. The present writer, however, when hereafter referring to type Rundle means the Tunnel Mountain section. Most geologists now regard the Rundle as a group containing the Livingstone, Mount Head, and Etherington formations. These have their type sections in the Highwood River area of the Canadian Rockies some 50 miles southeast of Banff.

The Livingstone formation consists of 1000 to 1500 feet of resistant light-colored crinoidal limestone interbedded with fine-grained, often cherty, limestones and dolomites of Osagean age. The unfossiliferous nature of the formation has hindered stratigraphic interpretation. In the type area two members are present (Douglas, 1953, Douglas and Harker, 1958). In ascending order these are the Pekisko and Turner Valley. In the adjacent plains a dark argillaceous unit intervenes between these two members. This unit is called the Shunda member[1] because of its presumed correlation (Moore, 1958; Penner, 1958b) with the type Shunda formation about 150 miles to the northwest. Lithostrotionid and associated faunas indicate that type Shunda is the lateral equivalent of the type Upper Banff formation (see text-figure 3). This correlation is in harmony with that of Moore (1958) who based his correlations mainly upon stratigraphic evidence. It remains to be shown, however, whether the Pekisko and Shunda of the Highwood area and adjacent plains are laterally related to the similarly named units north of Banff, or whether they are stratigraphically higher, i.e., equivalent to the lower and middle beds of type Rundle. In this report the term Livingstone will be applied to strata laterally and lithologically equivalent to the lower 1480 feet of type Rundle.

[1] The Pekisko, Shunda and Turner Valley are variously referred to by Canadian geologists as either members or formations.

The Mount Head formation is mainly Meramecian in age and consists of recessive, highly fossiliferous, dark-colored limestones, shaly limestones and calcareous shales between 400 and 700 feet thick (see Raasch, 1958; Nelson, 1958).

The Etherington formation is more resistant than the underlying Mount Head and contains light-weathering limestones and dolomites. The unit is Chesterian but lower beds may be Meramecian (*Lithostrotion genevievensis* zone) and upper beds Pennsylvanian (Nelson, 1958). North from Banff the Etherington carbonates disappear by grading laterally into clastics of the lower Tunnel Mountain formation (Nelson, ibid.). Until recently the Etherington in the area south of Banff was called "Tunnel Mountain formation" because of its presumed correlation with type Tunnel Mountain at Banff (Raasch, 1956, 1958; Harker and Raasch, 1958). The present writer (Nelson, 1958) has suggested that the former "Tunnel Mountain formation" (=Etherington) actually correlates lithologically and temporally with most of the uppermost 300 feet of type Rundle and not the overlying type Tunnel Mountain.

Twelve divisions of the Mississippian of the Canadian Rocky Mountains are recognized by the present writer. In ascending order these are: an unnamed division of the lower member and the lower part of the middle member of the Banff formation;

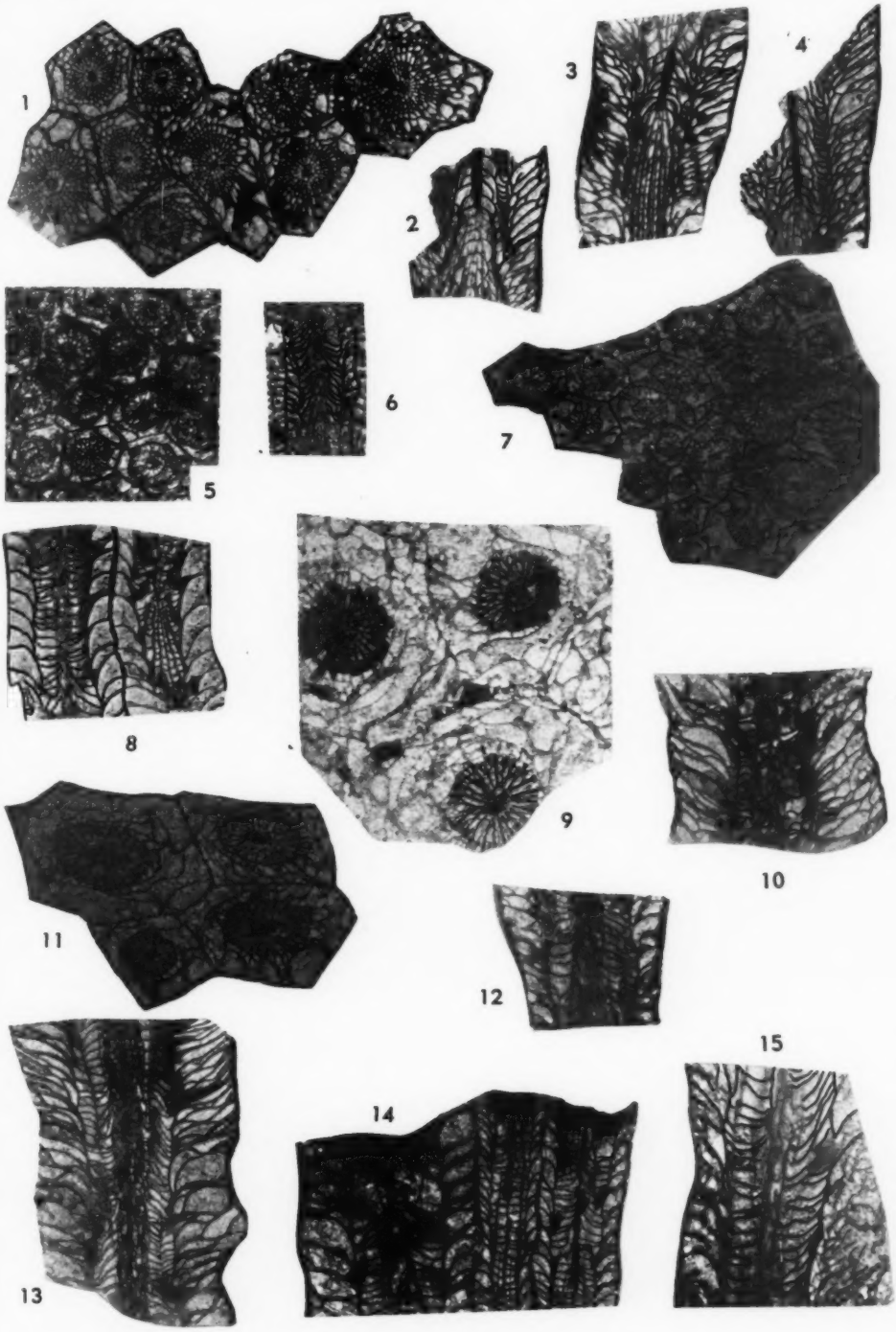
EXPLANATION OF PLATE 21

FIGS. *1–4*—*Lithostrotionella jasperensis* Kelly. Hypotype U. of A. No. 340: transverse and longitudinal sections, ×2.

5,6—*Lithostrotionella micra* Kelly. Hypotype U. of A. No. 339: transverse and longitudinal sections, ×2.

7,8—*Lithostrotionella bailliei* n. sp. Holotype U. of A. No. 321: transverse and longitudinal sections, ×2.

9–15—*Lithostrotionella shimeri* (Crickmay). Transverse and longitudinal sections. *9,10*, homeotype G.S.C. No. 4459d, ×3; *11–13*, topotype U. of A. No. 318 (*11*, ×1.7; *12*, ×2; *13*, ×2.6); *14*, hypotype U. of A. No. 320, ×2; *15*, portion of holotype (U. of A. Cb. No. 564), ×3.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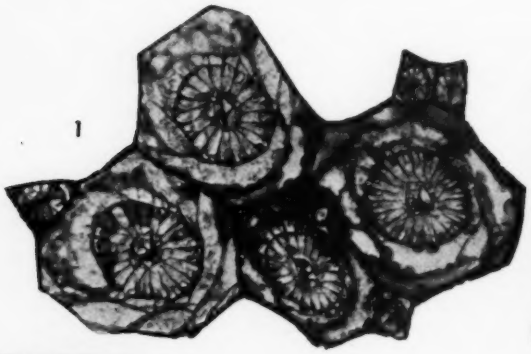
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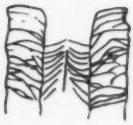
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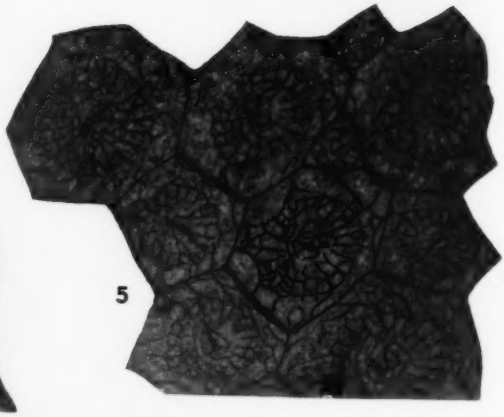
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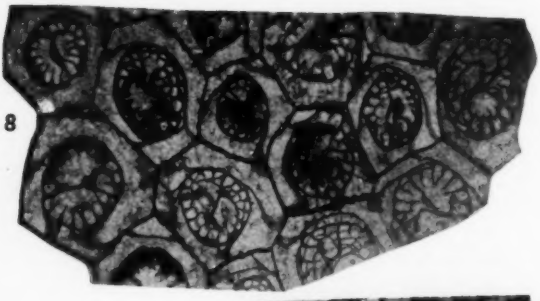
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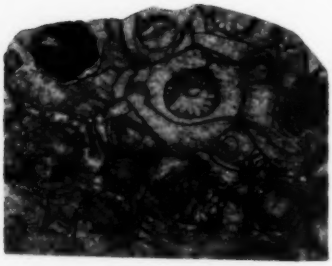
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the *Lithostrotionella jasperensis* zone of the upper part of the middle member; the *L. micra* zone of the lower part, and the *Lithostrotion mutabile* zone of the upper part of the upper member of the Banff and lowermost Livingstone; an unnamed division comprising lower and middle Livingstone beds; the *Lithostrotion sinuosum* zone of upper Livingstone; the *Lithostrotionella bailliei* n. sp. and *L. astraeiformis* zones of lower Mount Head; the *Lithostrotion whitneyi* zone of middle and upper Mount Head; the *L. arizelum* zone of uppermost Mount Head; the *L. genevievensis* zone of lower Etherington; an unnamed division for middle Etherington; and the *Lithostrotionella stelcki* n. sp. zone of upper Etherington.

Associated solitary corals and brachiopods have been used in determining limits of zones where colonial corals are absent in the sections portrayed on text-figure 2. Paucity of lithostrotionid fauna in the Banff and Livingstone formations makes delineation of contained zones difficult so that their lower and upper boundaries are approximate. Zonal boundaries for the Mount Head and Etherington formations are more precise.

Corals are most abundant in the Mount Head formation within the Mississippian succession, and *Lithostrotionella* dominate its lower part (*L. bailliei* and *L. astraeiformis* zones) and fasciculate *Lithostrotion* (*L. whitneyi* and *L. arizelum* zones) the middle and upper part. In the lower part of the formation these fossils tend to occur abundantly but scattered at three main horizons (occasionally termed "reefs" by some field workers). One, at the base of the formation, is called the "Lower *Lithostrotion* Reef." A second unnamed "reef" occurs between 92 and 98 feet above the base; and the third, the "Upper *Lithostrotion* Reef" extends between 145 and 153 feet above the base of the Mount Head (these figures refer specifically to Mount Rae). In this paper these coral beds are referred to as the lower, middle, and upper *Lithostrotionella* beds. The boundary for the *Lithostrotionella bailliei* and *L. astraeiformis* zones is placed at the middle *Lithostrotionella* bed. Differentiation between these two zones may not be valid because they contain many species in common. So far as known, however, *L. astraeiformis* does not extend below the middle *Lithostrotionella* beds nor *L. bailliei* above.

Certain of the lithostrotionid zones described in this paper have been recognized over considerable distances. The *Lithostrotionella jasperensis* zone has been recognized as far south as Arizona, and the *Lithostrotion mutabile* zone as far north as the South Nahanni River area of the Northwest Territories. The *Lithostrotion sinuosum* zone has been tentatively placed in the upper part of Brown's (1952) Rundle formation at Mount Greenock in the Jasper area, 175 miles northwest of Banff. Mount Head and Etherington zones are generally not recognized in the area between Banff and Jasper because of the unfossiliferous nature of these strata and the diachronic changes in lithofacies northward and eastward to clastics of the Tunnel Mountain formation. Still farther north, however, in the Peace River area, Mount Head equivalents are fossiliferous and both the *Lithostrotionella astraeiformis* and *Lithostrotion whitneyi* zones have been identified.

Comparison of the Canadian lithostrotionid fauna with that of the type Mississippian area of Upper Mississippi Valley is difficult. Most of the former coral species ap-

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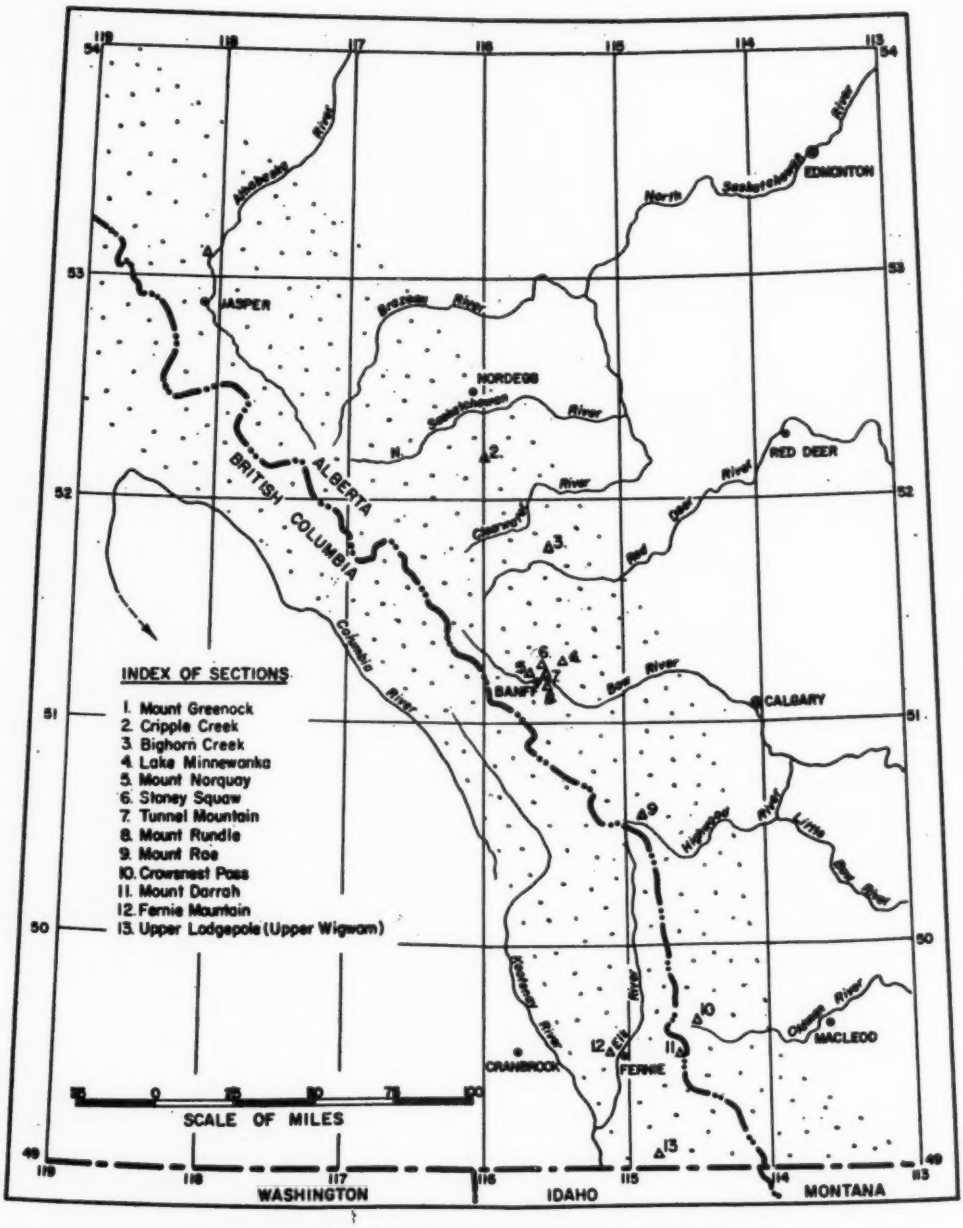
EXPLANATION OF PLATE 22

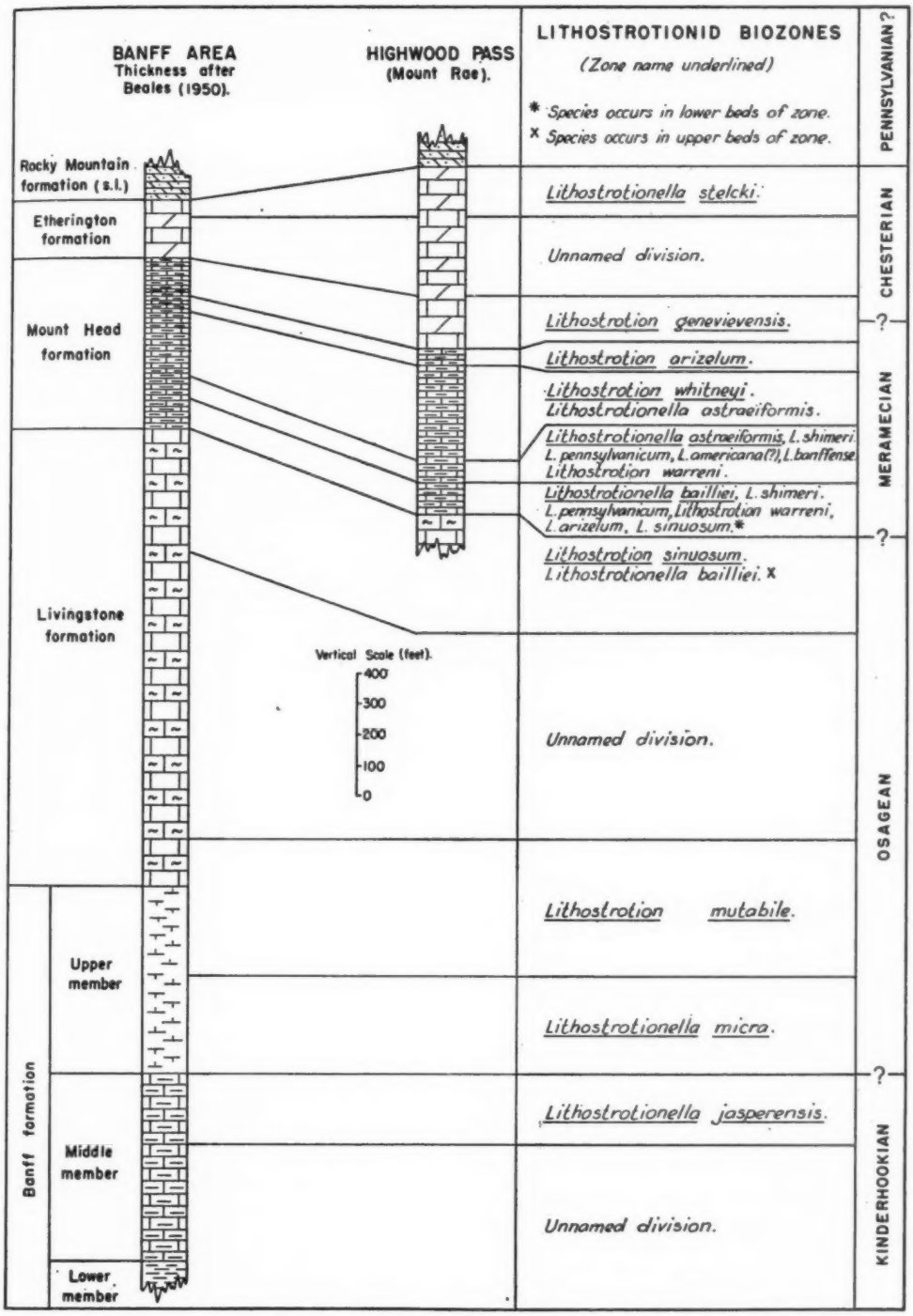
FIGS. *1–3*—*Lithostrotionella shimeri* (Crickmay). Hypotype U. of A. No. 319: transverse and longitudinal sections, ×2.

4–6—*Lithostrotionella pennsylvanicum* (Shimer). *4*, sketch of longitudinal structures of lectotype G.S.C. No. 4459a, ×1; *5–6*, hypotype U. of A. No. 333: transverse and longitudinal sections, ×2.

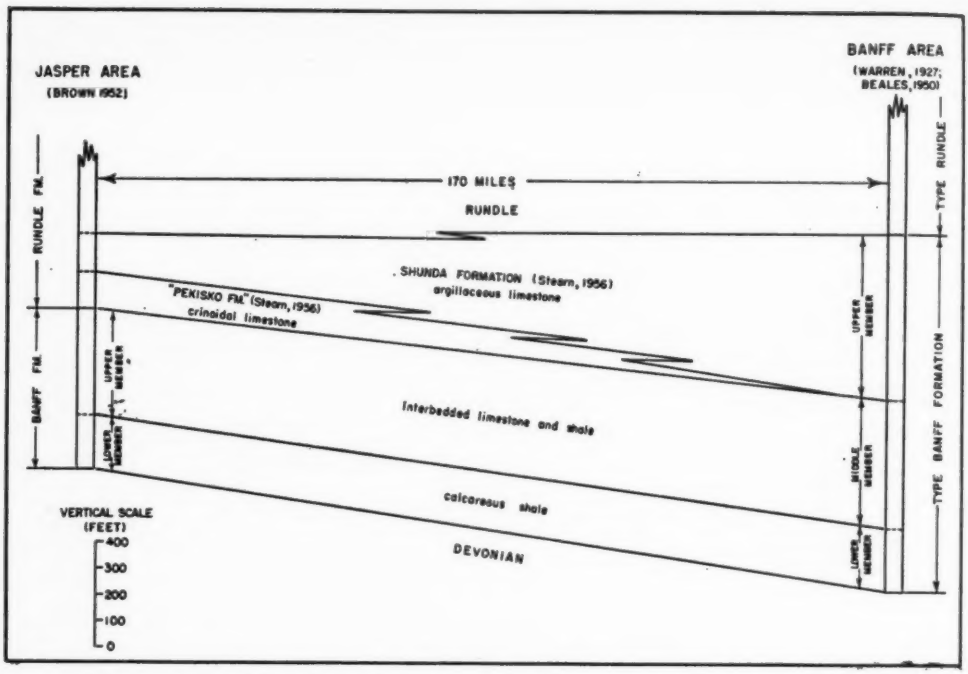
7–10—*Lithostrotionella astraeiformis* (Warren). Transverse and longitudinal sections. *7*, syntype, G.S.C. No. 8911, ×3; *8,10*, hypotype U. of A. No. 322, ×2; *9*, topotype U. of A. No. Cb. 179, ×2.



TEXT-FIG. *1*—Sketch map showing position of fossil localities. Extent of Rocky Mountains is indicated by stippled area.



TEXT-FIG. 2—Mississippian lithostrotionid zones and contained species.



TEXT-FIG. 3—Banff-Rundle stratigraphic relationships in Rocky Mountain front ranges between the Banff and Jasper areas, Alberta.

pear indigenous: *Lithostrotion genevievensis* Easton being the only species common to both areas. In the writer's opinion a redescription of the primary type and topotype specimens of Mississippi Valley would probably bring out more conspecific relationships between the two areas than are apparent at present. For example, it was noted (see Description of Species) that *Lithostrotionella jasperensis* Kelly is close to the Chouteau species *Lithostrotion microstylum* White; and that *Lithostrotion arizelum* (Crickmay) is similar to the St. Louis *L. proliferum* Hall. The specific identity of these corals, however, has not been rigorously delimited.

The writer wishes to extend his gratitude to officials of The British American Oil Company, Limited, particularly Dr. A. D. Baillie, Calgary, whose generous support and encouragement has made this study possible. Assistance has also been rendered by grants from the University of Alberta and the National Research Council. Dr. C. R. Stelck, Dr. P. S. Warren, and Dr. R. E. Folinsbee have provided helpful criticism during this study. Miss E. Dingman and Mr. J. Cole kindly supplied the writer with technical assistance during preparation of this paper.

DESCRIPTION OF SPECIES

Genus LITHOSTROTIONELLA Yabe and Hayasaka

LITHOSTROTIONELLA JASPERENSIS Kelly

Pl. 21, figs. 1–4

Lithostrotionella jasperensis Kelly, 1942, p. 356, pl. 51, figs. 3,6.

Lithostrotion (*Lithostrotionella*) *circinatus* Easton and Gutschick, 1953, p. 19, pl. 3, figs. 5,6.

Horizon and Locality.—The species is rare in the Banff formation. It has so far been found in strata coeval with the upper part of the middle member of type Banff formation.

Holotype, G.S.C. No. 9647: from "just below the summit of the northeast end of the spur east of the watershed of Rocky Pass, Mountain Park area, Alberta" (Kelly, 1942).

Hypotype, U. of A. No. 340: Cripple Creek, Alberta (Lat. 52° 12′, Long. 116° 00′).

Description.—The following is based upon hypotype, U. of A. No. 340, a well preserved fragment of a corallum:

Transverse Section: Corallites are approximately equidimensional and have an average diameter of about 9 mm. with corresponding tabularium width of 4 mm. The dissepimentarium-tabularium wall is not well defined. Intercepts are common in the outer zone. Between 16 and 18 thinly wedge shaped major septa extend most of the way to the center, and in the majority of corallites join the columella. Minor septa, within the tabularium, are a third to half the length of the majors. Both septa commonly extend into the dissepimentarium for between one third to one half its width. The columella, originally very thin and somewhat elongate, has been thickened by secondary deposits and has an almond-shaped outline.

Longitudinal Section: The dissepimentarium is about 1 mm. wide in an immature 6 mm. corallite and consists of a single row of dissepiments, commonly incomplete, sloping downward at an angle of about 45 degrees. Because of this incompleteness dissepimental measurements are uncertain: an estimated 10 occur in a vertical distance of 5 mm. Between 8 and 9 tabulae occur in the same interval. All slope steeply upward but the pattern is very irregular. They are commonly incomplete, imparting a vesicular appearance to the tabularium. The general tendency is to have a rough sigmoidal curvature, becoming flatter near the columella and often near the tabularium wall. The former is very thin. In a mature 10 mm. corallite with a 3 mm. wide dissepimentarium the tabular and dissepimental pattern is rather similar to that of an immature corallite. Dissepiments are closely spaced, slope downward at a horizontal angle of between 20 and 30 degrees and may or may not steepen near the tabularium wall. They are commonly discontinuous with 10 to 13 occurring in 5 mm. About 8 tabulae occur in the same distance. They sloped steeply upward and are commonly incomplete, particularly near the outer margins. They generally slope at an angle of around 45 degrees becoming flatter near the columella and occasionally flatter near the tabularium wall. Tabular pattern apparently is quite variable for another mature corallite has almost all incomplete tabulae imparting a rather openly vesicular appearance to the tabularium. They all, however, slope upward to the columella.

Discussion.—Transverse details of the hypotype agree well with those of the holotype (figured by Kelly). Only a longitudinal thin section (also figured by Kelly) of the holotype was available to the present writer. This section cuts most corallites obliquely and does not show good axial detail. No well preserved tabulae are present. The writer suspects that Kelly based his description of tabular pattern on dissepiments rather than on tabulae. Where tabulae could be observed on the holotype they appear to have the same pattern as on the hypotype, i.e. steeply sloping upward and becoming flatter near the columella.

Lithostrotionella jasperensis appears to be conspecific with *L. circinatus* Easton and Gutschick from the Redwall limestone of Arizona. It is very closely related to the Chouteau species *Lithostrotion microstylum* White but differs in its growth habit and by having a lonsdaleoid dissepimentarium.

LITHOSTROTIONELLA MICRA Kelly
Pl. 21, figs. 5,6

Lithostrotionella micra Kelly, 1942, p. 357, pl. 50, fig. 7.

Horizon and Locality.—Diagnostic of strata correlating with the lower part of the upper member of type Banff formation, i.e., the lower part of the Shunda formation.

Holotype, G.S.C. No. 9648: from "just below the summit of the northeast end of the spur east of the watershed of Rocky Pass, Mountain Park area, Alberta" (Kelly, 1942).
Hypotype, U. of A. No. 339: base of Shunda formation, Bighorn Creek, Alberta (Lat. 51° 46′, Long. 115° 30′).

Description.—The following is based upon hypotype, U. of A. No. 339, a fragment of a corallum:

Transverse Section: Corallites are uniformly sized, six sided, and have an average diameter of 4 mm., of which about 3 mm. belongs to the tabularium. The dissepimentarium has relatively few intercepts. Usually 14 thin major septa extend to the centre where they tend to abut against the columella imparting a rough bilateral symmetry about the cardinal-counter plane. Minor septa are a third to a fourth the length of the majors. The columella, formed by extension of the counter septum, is very thin and elongate.

Longitudinal Section: The dissepimentarium consists of a single row of variably spaced and sized vesicular dissepiments, with usually 5 to 7 occurring in a vertical distance of 5 mm. The tissue extends as near horizontal or gently inclined downward over most of the dissepimentarium and becomes steeply, almost vertically inclined down to join the tabularium. Tabulae are very thin; between 10 and 12 usually occur in 5 mm. They are rather variable in pattern but com-

monly are inclined upward, at a horizontal angle of between 20 and 30 degrees, to the columella. Most leave the dissepimental wall and join the columella without marked deflection but may occasionally become near horizontal near the former and gently deflected upward near the latter. The columella appears very thin and rod-like.

Discussion.—Only a transverse thin-section of the holotype (figured by Kelly) was available to the present writer. Specimens which he is referring to the species are almost identical with the former in transverse details. They appear to differ in longitudinal aspect in that tabulae are generally inclined upward whereas Kelly stated that tabulae of the holotype were usually nearly horizontal, inclined upward near the columella and downward near the tabularium wall.

LITHOSTROTIONELLA BAILLIEI n. sp.
Pl. 21, figs. 7,8

Horizon and Locality.—The species is rare but so far as known is characteristic of beds immediately above and below the Mount Head-Livingstone contact as exposed at Mount Rae, Alberta.

Holotype, U. of A. No. 321: Livingstone formation; 15 feet below the Mount Head-Livingstone contact, Mount Rae, Alberta.

Description:—The following is based upon the holotype, a fragment of a corallum:

Transverse Section: The corallum consists of polygonal, generally six-sided, fairly uniformly sized corallites typically having widths between 5 and 6 mm. with corresponding tabularium diameters of 3 and 4 mm. respectively. The dissepimentarium shows few intercepts. Major septa are thin, number between 17 and 18 and usually extend to, or close to, the centre. Minor septa are generally present and are one-quarter or less the length of the major septa. The columella is formed by extension of the counter septum. In immature corallites it is thin and compressed. In mature individuals it is often thickened and nearly circular with a diameter of about ½ mm. Occasionally obscure septal lamellae-like structures are preserved.

Longitudinal Section: Dissepiments are in a single series and are about as high as wide. They leave the thecal wall nearly at right angles and slope gently away from it for over one-half the dissepimentarium width and then curve steeply downward to join the tabularium wall. Usually 3 or 4 dissepiments occur in a vertical distance of 5 mm. Tabulae are thin, usually about 12 occur in the same interval. The majority of tabulae sag gently between the tabularium wall and columella. The remainder may either extend as near horizontal across the tabularium or slope upward with a horizontal angle of 30 degrees to join the columella.

Discussion.—The species is named in honour of Dr. A. D. Baillie, of The British American Oil Company Limited, Calgary, Alberta.

Lithostrotionella bailliei is closest to *L. micra* Kelly but differs in having corallites consistently 1 to 2 mm. greater in diameter, and with larger dissepiments.

LITHOSTROTIONELLA SHIMERI
(Crickmay)
Pl. 21, figs. 9–15; pl. 22, figs. 1–3

Lithostrotion pennsylvanicum (Shimer), 1926 (partim.), p. 27.
Lithostrotionella pennsylvanica (Shimer). Kelly, 1942, p. 352, pl. 50, figs. 1,2,5,6,8.
Lonsdaleia pennsylvanica (Shimer). Crickmay, 1955, p. 13, pl. 1, figs. 11,12.
Lonsdaleia shimeri Crickmay, 1955, p. 13, pl. 1, figs. 9,10.

Horizon and Locality.—Common in the lower Mount Head formation, ranging from the lower to the upper *Lithostrotionella* beds.

Holotype (Crickmay Collection, Imperial Oil Company, Limited, Calgary); Topotype, U. of A. No. 318; Crickmay's bed 6, section 2, Rundle of Lake Minnewanka.
Hypotype, U. of A. No. 319: basal Mount Head formation, fault slice 4 of Rundle, Crowsnest Pass (see Nelson, 1959).
Hypotype, U. of A. No. 320: 1640 feet above base of Rundle group, Tunnel Mountain, Alberta.

Remarks.—The writer has sectioned a portion of the holotype and found it conspecific with "cotype" G.S.C. No. 4459d of *L. pennsylvanicum* (Shimer). As remarked under the latter species, this "cotype" is designated as a homeotype of *L. shimeri*.

Description.—The following is based upon a portion of the holotype (numbered Cb 564 in the University of Alberta collection), a very poorly preserved specimen:

Transverse Section: The average width of mature corallites is about 10 mm. with a corresponding tabularium diameter of between 5 and 6 mm. In immature corallites with a diameter of about 4 mm. the tabularium is about 2 mm. wide and has about 13 major septa extending halfway to the center. Minor septa are absent. The columella is simple, plate-like and formed by extension of the counter septum. In relatively well preserved

matuer corallites dissepimental intercepts are rare in the outer zone. Between 19 and 21 major septa extend about three-quarters the distance to the center and reach or nearly touch the wide axial complex. Minor septa are usually present and are about one-third the length of the majors. The axial complex may be up to 2 mm. in diameter. It is poorly preserved but appears to be a meandrose columella surrounded by 5 or 6 septal lamellae-like structures which may either have a very rough radial pattern or be vermiform.

Longitudinal Section: Good sections are very difficult to obtain. The following is based upon a 10 mm. diameter corallite. The dissepimentarium is about 2.5 mm. wide and consists of a single row of vesicular dissepiments. They leave the thecal wall at a vertical angle of between 45 and 90 degrees, slope downward becoming near-vertical toward the tabularium. Between 4 and 5 occur in a vertical distance of 5 mm. Usually 8 to 10 tabulae occur in the same interval. They are deflected downward at the tabularium wall, become near-horizontal over most of the tabularium and tend to abut directly against the axial complex. The latter is not well preserved. It appears to consist of a series of three or four loosely anastomosing lines some of which are probably intercepts of septal lamellae-like structures.

Topotype, U. of A. No. 318, shows that in transverse section some major and occasionally minor septa extend partway across the dissepimentarium. In longitudinal section tabulae may not be deflected downward near the tabularium wall but may either extend as near horizontal over most of the tabularium or rise gently with a horizontal angle of between 10 and 30 degrees, steepening near the axial region. Except for the wide axial complex, the longitudinal aspect of these corallites with sloping tabulae is much like those of *L. pennsylvanicum.*

Discussion.—Crickmay (1955) has suggested that this species belongs in *Lonsdaleia* because of its lonsdaleoid dissepimentarium and presumably because he considered the tabulae lonsdaleoid. The present writer is placing it in *Lithostrotionella* because no sign of tabellae—structures characteristic of *Lonsdaleia*—have been found in *Lithostrotionella shimeri.*

A considerable array of coralla having corallites similar in size to, and internal structures nearly indentical with the holotype and topotype of *L. shimeri* have been studied by the present writer. These coralla have a rather wide vertical range (see *Horizon and Locality*). They differ from the holotype and topotype in that minor septa are relatively short or absent. Examples of these specimens are hypotypes, U. of A. Nos. 319 and 320. The present writer is placing these specimens in *L. shimeri* because he regards development of minor septa as an individual characteristic. Attempts to stratigraphically zone and differentiate specimens referred to *L. shimeri* on the basis of such characteristics as pattern and spacing of tabulae and/or dissepiments have failed because there is considerable variation of these features within a corallum and even within a corallite.

LITHOSTROTIONELLA (THYSANOPHYLLUM) ASTRAEIFORMIS (Warren)

Pl. 22, figs. 7–10

(?) *Lithostrotion* sp. Shimer, 1926, p. 29.
Diphyphyllum astraeiforme Warren, 1927, p. 44, pl. 3, figs. 2,3; pl. 6, fig. 1.
Lithostrotion banffense Warren, 1927 (partim), p. 46.
(?) *Lithostrotionella simplex* Hayasaka, 1936, p. 70, pl. 14, figs. 4a,b.
Lithostrotionella astraeiformis (Warren). Kelly, 1942, p. 352.
Thysanophyllum astraeiforme (Warren). Crickmay, 1955, p. 13.

Horizon and Locality.—Lower Mount Head formation, from the middle to the upper *Lithostrotionella* beds. Very rarely the species will range for about 100 feet above the latter bed. *Lithostrotionella astraeiformis* is the most abundant colonial tetracoral in the Mississippian of the southern Canadian Rockies.

Syntypes, G.S.C. No. 8911, 8911a–c; topotype, U. of A. No. Cb. 179: probably from 1640 feet above the base of the Rundle, Tunnel Mountain, Alberta.
Hypotype, U. of A. No. 322: between 92 and 98 feet above the base of the Mount Head formation, Mount Rae, Alberta.

Remarks.—In the original description Warren (1927) stated that the species occurred "near the top of the Rundle limetone on Tunnel Mountain." The present writer is of the opinion that the type locality is the upper *Lithostrotionella* beds (1640 feet above the Rundle base) because both Warren's topotype (Cb. 179) and the present writer's specimens from this locality are

almost identical lithologically and internally with the holotype.

The primary types consist of four specimens and a longitudinal and transverse thin section of one corallite. Patterns of tabulae and dissepiments in the former section are very similar to those illustrated by Warren (pl. 3, fig. 3). The transverse thin section is poorly preserved and shows only traces of septa whereas transverse polished sections of the syntypes show well developed ones, slightly shorter than indicated by Warren (pl. 3, fig. 2). In longitudinal polished sections all corallites appear thysanophylloid. Transverse sections, however, do show that some have a columella and are thus lithostrotionelloid.

Numerous longitudinal and transverse sections have been made of topotype, U. of A. No. Cb. 179. Corallites are predominantly thysanophylloid. Some however, were found to be *Lithostrotionella* genomorphs. The present writer has numerous specimens of *Lithostrotionella astraeiformis* from the southern Canadian Rockies. Corallites are rarely *Thysanophyllum* genomorphs. The majority have a columella and both transversely and longitudinally are very similar to the *Lithostrotionella* genomorph corallites of the topotype. Thus the present writer is including in this species specimens in which corallites may be either of the *Thysanophyllum* or *Lithostrotionella* genomorph.

Description.—The following is based on topotype, U. of A. No. Cb. 179, a fragment of a corallum:

Transverse Section: Corallites are rather variable in size. The average width of mature individuals is about 8 mm. with a corresponding tabularium diameter of between 5 and 6 mm. Intercepts are not numerous in the dissepimentarium. Between 16 and 20 major septa extend from a third to a fourth the distance to the center. Minor septa are absent. A columella is present in about half of the corallites. Its development is probably sporadic for it does not commonly appear in longitudinal sections. It is very thin and formed by extension of the counter septum. Occasionally it may bend and be hook-shaped.

Longitudinal Section: In a *Thysanophyllum* genomorph corallite about 10 mm. in diameter, the dissepimentarium is 3 mm. wide and consists of a single row of large vesicular dissepiments, 2 or 3 of which occur in a vertical distance of 5 mm. Dissepiments leave the thecal wall nearly at right angles, curve downward very gently, and steepen about two-thirds the distance from the thecal wall. Tabulae are about 1 mm. apart and may be nearly flat, or, more commonly, concave upward. In a *Lithostrotionella* genomorph corallite having about the same diameter, pattern and spacing of dissepiments and spacing of tabulae are about the same as in the *Thysanophyllum* genomorphs. Most tabulae are gently concave upward between columella and tabularium wall. Occasionally they may be flat, or very gently inclined upward. The columella is usually rod-like but sometimes is gently flexuous.

Hypotype, U. of A. No. 322 is the best preserved specimen of this species. It has more uniformly sized corallites than the topotype, with an average diameter of about 7 mm. and corresponding tabularium width of about 4.5 mm. They are nearly all *Lithostrotionella* genomorphs. In transverse section the columella is often irregularly meandrine and occasionally may be very loosely vesicular. Longitudinal sections are very similar to those of the topotype. Tabulae, however, are more concave upward between columella and tabularium wall.

Discussion.—As remarked under *L. banffense* (Warren), "cotype" No. 8912a of that species is considered to be *L. astraeiformis* and is designated as a homeotype only of *L. astraeiformis*.

Some of the specimens which Shimer (1926) referred to *Lithostrotion* sp. may pos

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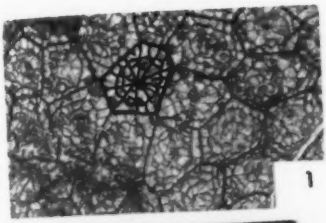
EXPLANATION OF PLATE 23

FIGS. *1,2—Lithostrotion* (?) *macouni* Lambe. Syntype G.S.C. No. 4327: transverse and longitudinal sections, ×3.

3—Lithostrotionella americana Hayasaka (?). Hypotype U. of A. No. 328: transverse section, ×2.

4,5—Lithostrotionella banffense (Warren). Lectotype G.S.C. No. 8912: transverse and longitudinal sections, ×2.

6–10—Lithostrotionella stelcki n. sp. Transverse and longitudinal sections, ×2. *6,7*, holotype U. of A. No. 329; *8–10*, paratype U. of A. No. 330.



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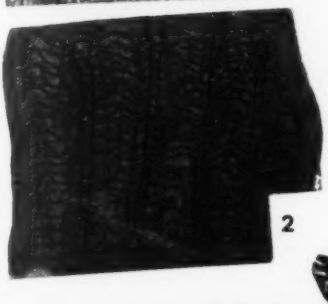

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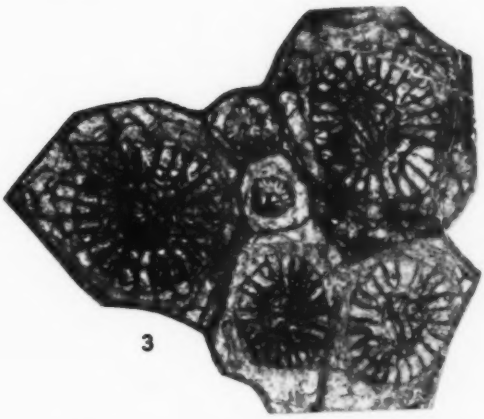

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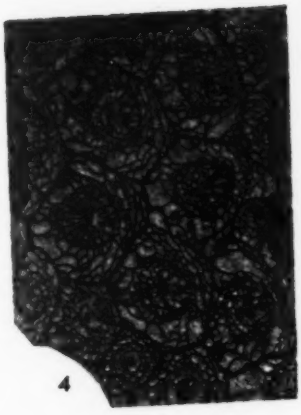

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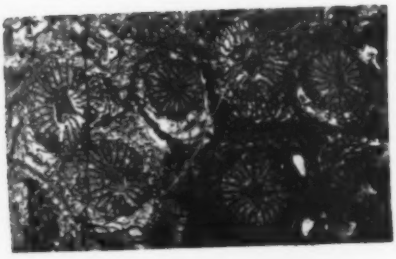

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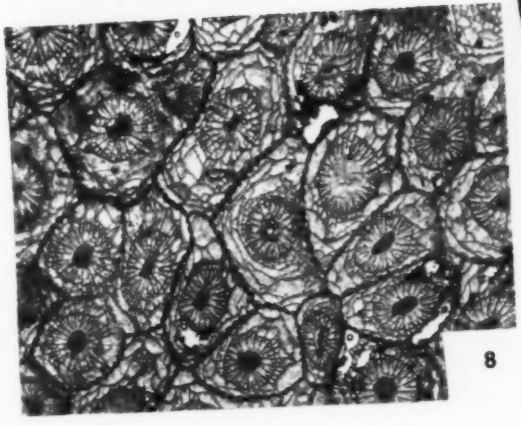

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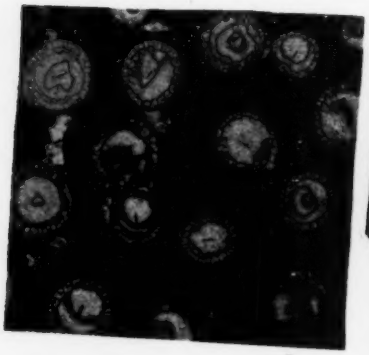
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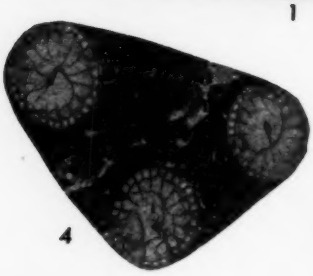
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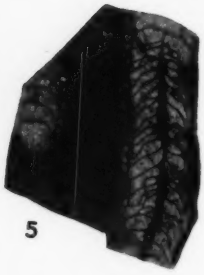
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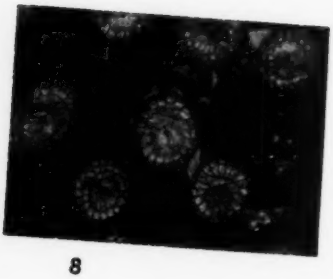
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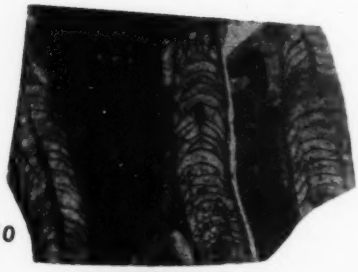
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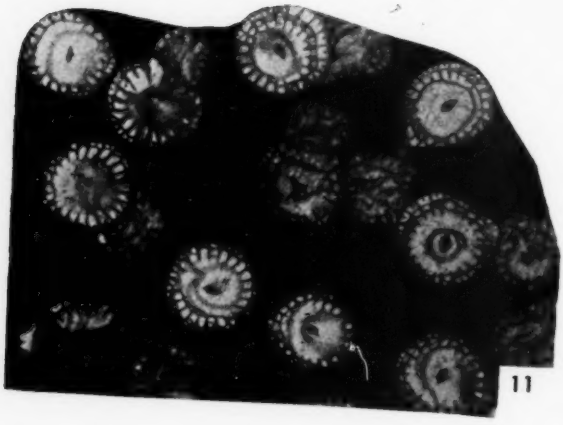
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sibly be *Lithostrotionella astraeiformis*. These specimens were described as having corallites with uniform diameters of about 4 mm. One of the localities where they were collected is Shimer's bed 8 of section 2, Lake Minnewanka. (Crickmay's (1955) bed 6). Some specimens of *L. astraeiformis* collected from this bed by the present writer have small diameter corallites but unlike Shimer's specimens they show considerable variation in size. Most are around 4 mm. but some range as high as about 8 mm. in diameter.

LITHOSTROTIONELLA PENNSYLVANICUM (Shimer)
Pl. 22, figs. 4–6

Lithostrotion pennsylvanicum Shimer, 1926 (partim), p. 27, pl. 5, figs. 3,5.
(non) *Lithostrotionella pennsylvanica* (Shimer). Kelly, 1942, p. 352, pl. 50, figs. 1,2,5,6,8.
(non) *Lonsdaleia pennsylvanica* (Shimer). Crickmay, 1955, p. 13, pl. 1, figs. 11,12.

Horizon and Locality.—Lower Mount Head formation. The exact range is not known but is probably from the lower to the upper *Lithostrotionella* beds. The species is rare in the Mississippian of the Rockies.

Lectotype, G.S.C. No. 4459a: Shimer's (1926) bed 4, section 3a, Rundle of Lake Minnewanka.
Hypotype, U. of A. No. 333: 1640 feet above the base of the Rundle, Tunnel Mountain, Alberta.

Remarks.—The primary types of *Lithostrotionella pennsylvanicum* appear to belong in two distinct species: *L. pennsylvanicum* (Shimer) and *L. shimeri* (Crickmay). The types are labelled as being from bed 4, section 3a, Rundle of Lake Minnewanka area, Alberta, and are represented by four specimens labelled as "cotypes" G.S.C. Nos. 4459, 4459a, 4459b, and 4459d, respectively. Cotypes Nos. 4459 and 4459b are not polished or sectioned so that their internal detail is unknown. The former specimen was illustrated by Shimer on figure 4 of plate 5. Cotype 4459b has not been figured.

Cotype No. 4459a, the specimen illustrated by Shimer on figure 3 of plate 5, has been polished transversely and longitudinally. Longitudinal sections show pattern of tabular and columella to be quite similar to Shimer's illustration of *L. pennsylvanicum*. His drawing (plate 5, figure 5) is stated to have been based upon several specimens. Because cotype No. 4459a is closest to the species as interpreted by Shimer it is designated as both holotype and lectotype of *L. pennsylvanicum* (Shimer). Shimer referred this species to *Lithostrotion*. A transverse section of the holotype, however, shows a lonsdaleoid dissepimentarium so that it belongs in *Lithostrotionella*.

"Cotype" No. 4459d appears to belong to a different species, viz. *Lithostrotionella shimeri* (Crickmay). The axial structure is complex and tabulae tend to be nearly flat or convex or concave upward on either side of the columella. Presumably it is the specimen upon which Crickmay (1955) based his interpretation of *L. pennsylvanicum*, although he stated that the "type specimen" came from bed 14, section 2 of the Rundle at Lake Minnewanka. The writer has compared "cotype" No. 4459d with a portion of the holotype of *L. shimeri* (Crickmay) and found the two conspecific. Therefore "cotype" No. 4459d is a homeotype only of *L. shimeri* (Crickmay).

Description.—The holotype (G.S.C. No. 4459a) of *Lithostrotionella pennsylvanicum* (Shimer) is a fragment of a corallum. Details on a small transverse cut are rather obscure, whereas longitudinal sections show well preserved structures. Shimer's interpretation of

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EXPLANATION OF PLATE 24

FIGS. *1–3—Lithostrotion mutabile* (Kelly). Hypotype U. of A. No. 341: transverse and longitudinal sections, ×2.
4–10—Lithostrotion sinuosum (Kelly). Transverse and longitudinal sections. *4,5*, holotype G.S.C. No. 8913, ×3; *6,7*, hypotype U. of A. No. 342, ×2; *8–10*, hypotype U. of A. No. 343, ×2.
11–14—Lithostrotion warreni n. sp. Holotype U. of A. No. 338: transverse and longitudinal sections, ×2.

the species shows more steeply inclined tabulae than are present in this specimen.

Transverse Section: Corallites vary in width from 5 mm., with estimated tabularium diameter of 2 mm., to 17 mm. with a corresponding diameter of 7 mm. The fragmentary nature of the corallum prevents estimation of average corallite diameter. Most, however, appear to be less than 17 mm. In a 13 mm. corallite intercepts are fairly common in the dissepimentarium. The tabularium diameter is about 5.5 mm. and an estimated 22 major septa extend for about three-quarters the distance to the center. Minor septa appear to be absent. The columella is simple and compressed. Weathered corallites, however, show about 4 to 5 septal lamellae-like structures on the columella.

Longitudinal Section: The following description is based upon a 17 mm. diameter corallite. In the dissepimentarium the tissue is often discontinuous. Usually dissepiments leave the thecal wall at anywhere between 90 degrees to a vertical angle of 60 degrees, slope downward for about three-quarters of the dissepimentarium width and steepen to near vertical before joining the wall of the tabularium. Between 4 and 5 dissepiments usually occur in a vertical distance of 5 mm. Usually 8 to 10 tabulae occur in the same interval. Tabulae rise from the tabularium wall with a horizontal angle of 30 degrees, occasionally less, and steepen before joining the columella. Some are deflected downward or sag near the tabularium wall. The columella is not well preserved. Another corallite with a diameter of 14 mm., however, shows a simple rod-like columella. The patterns of dissepiments and tabulae are much the same as in the above corallite except that tabulae steepen to near vertical before joining the columella.

Hypotype, U. of A. No. 333 is very close, in its longitudinal features, to those of *L. pennsylvanicum* as interpreted by Shimer. Supplementary morphology of the species is as follows:

Transverse Section: The average diameter of mature corallites is about 12 mm. with a corresponding tabularium width of 7 mm. About 20 thin major septa extend from one-half to three-quarters of the distance to center. Minor septa are usually absent. The columella is elongate, thin and is usually surrounded by 3 or 4 septal lamellae-like structures and tabular intercepts.

Longitudinal Section: A corallite about 9 mm. in diameter has a dissepimentarium between 1.5 and 2 mm. wide. Usually about 5 dissepiments occur in a vertical distance of 5 mm. They are quite variable in shape, ranging from vesicular to transversely-elongate. Most leave the thecal wall nearly at right angles or at a low horizontal angle, slope gently downward and steepen near the tabularium wall. Tabulae are closely spaced; about 10 in 5 mm. The majority leave the tabularium wall with a low horizontal angle but shortly steepen to one of about 45 degrees, and on approaching the columella become near-vertical. The columella appears simple and rod-like.

Discussion.—Lithostrotionella pennsylvanicum (Shimer) as interpreted by the present writer, is very close to *L. banffense* (Warren) and the two may be conspecific. The only major difference is in the size of mature corallites: those of *L. pennsylvanicum* are consistently larger. The columella of *L. pennsylvanicum* is rather complex in transverse section while that of *L. banffense* appears simple. It is possible, however, that the axial structure of the latter may have been obscured by secondary deposits.

LITHOSTROTIONELLA AMERICANA
Hayasaka (?)
Pl. 23, fig. 3

Lithostrotionella americana Hayasaka, 1936, p. 62, pl. 14, figs. 1,2.

Horizon and Locality.—This species has so far been found only in the upper *Lithostrotionella* beds of the Mount Head formation.

Hypotype, U. of A. No. 328: between 145 and 153 feet above base of Mount Head formation, Mount Rae, Alberta.

Description.—This species is represented by two fragmentary and rather poorly preserved specimens of which hypotype, U. of A. No. 328 is most complete. Transverse details are good in the latter specimen but longitudinal ones are rather obscure. The following description is based upon it:

Transverse Section: Corallites are rather variable in size, ranging from 4 mm. up to 15 mm. in diameter, with the average around 12 mm. In 15 mm. diameter corallites 23 to 25 thinly wedge-shaped major septa extend about halfway to the center. Minor septa are short or absent. The inner half of the tabularium is made up of a loosely sub-reticulate to vermiform complex of tabular intercepts about 4 or 5 mm. wide. The columella is not always apparent. When recognizable it is elongate and compressed.

Longitudinal Section: The best section was obtained on a 15 mm. diameter corallite. The dissepimentarium here is about 3 mm. wide and consists of a single row of rather steeply inclined vesicular to elongate dissepiments, 3 of which generally occur in a vertical distance of 5 mm. Between 4 and 5 tabulae usually occur in the same distance. They curve upward to the axial

region with a horizontal angle of about 45 degrees. The columella is not preserved. There is a considerable variation in tabular pattern in other corallites. A few are thysanophylloid with tabulae extending across the tabularium as near horizontal or gently concave upward. In most, tabulae slope upward and are considerably contorted in the axial region. The columella cannot be recognized.

Discussion.—Although the Rundle specimens are very close to the holotype in transverse detail, they are questionably referred to the species because of their axially contorted tabulae. According to Hayasaka, tabulae of the holotype are steeply inclined to the columella. He made no mention of contortion.

LITHOSTROTIONELLA BANFFENSE (Warren)
Pl. 23, figs. 4,5

Lithostrotion banffense Warren, 1927, p. 46, pl. 3, figs. 5,6; pl. 5.
Lithostrotionella banffensis (Warren). Kelly, 1942, p. 354.
Lithostrotion banffense (Warren). Crickmay, 1955, p. 12, pl. 1, figs. 13,14.

Horizon and Locality.—The species is rare in the Rundle of the Rockies; the cotypes are the only specimens known to the writer. Warren (1927) stated that it was collected near the top of the unit on Stoney Squaw Mountain, Banff, Alberta. Although subsequent search by the present writer failed to find topotype specimens, he is of the opinion that the holotype was derived from the upper *Lithostrotionella* beds (lower Mount Head formation) because this horizon is the only one bearing abundant colonial corals in the Banff area.

Remarks.—The types of this species are represented by two specimens labelled as cotypes, G.S.C. Nos. 8912 and 8912a, respectively. Cotype No. 8912a is *Lithostrotionella astraeiformis* (Warren) and is here designated as a homeotype only of that species. Cotype No. 8912 shows most of the characteristics of the species as interpreted by Warren and is designated as the holotype and lectotype of *L. banffense.* A longitudinal and a slightly oblique transverse thin section were available. The latter shows a well developed lonsdaleoid dissepimentarium indicating that the species belongs in *Lithostrotionella.* Because of this dissepimentarium it does not seem reasonable to place the species in *Lithostrotion* as was suggested by Crickmay (1955).

Description.—The following is based upon the two thin sections of the holotype, G.S.C. No. 8912:

Transverse Section: Corallites vary in width from 4 mm., with corresponding tabularium diameter of about 2.5 mm., up to 8 mm. with a corresponding diameter of 4 mm. The average corallite diameter is about 6 mm. In 4 mm. corallites dissepimental intercepts are common in the dissepimentarium (possibly because of the obliquity of the section). Approximately 20 major septa extend from one-half to three-quarters the distance to the center. Minor septa are absent. The columella is almond-shaped and appears formed by extension of the counter septum. In a 7 mm. diameter corallite dissepimental intercepts are also common. About 20 major septa extend usually three-quarters of the distance to center and reach or nearly reach the columella. Minor septa are absent. The columella is not well preserved. It usually appears as a solid circular or ovoid structure about 1 mm. wide.

Longitudinal Section: Good sections are available only on 6 mm. diameter corallites. The dissepimentarium is about 1 mm. wide and usually consists of a single row of large vesicular dissepiments. Some corallites, however, have a rather complex dissepimentarium because of numerous discontinuous dissepiments. Where dissepiments are in a single row, usually 5 occur in a vertical distance of 5 mm. They leave the thecal wall at a vertical angle of between 75 and 90 degrees, curve gently downward and steepen, becoming near vertical toward the tabularium wall. Tabulae are thin, often discontinuous; generally 10 occur in 5 mm. Most have a slope of about 45 degrees from the tabularium wall to columella. Commonly they have a sigmoidal curvature tending to be steeper near the tabularium wall and the columella. The columella is simple and rod-like.

LITHOSTROTIONELLA STELCKI n. sp.
Pl. 23, figs. 6–10

Horizon and Locality.—Upper Etherington formation: the species is very rare, so far represented only by the types.

Holotype, U. of A. No. 329: 250 feet below Rocky Mountain-Etherington contact, Fernie Mountain, British Columbia.
Paratype, U. of A. No. 330: from rubble, 525 feet above base of Etherington formation, Mount Rae, Alberta.

Remarks.—Although the holotype is more poorly preserved than the paratype it is thought best to so designate the former

specimen because it has a known stratigraphic position at the type locality. The paratype was collected from rubble. Attitude of strata where collected, and the angularity of the specimen, however, suggest that it is derived from beds close by: probably the *Syringopora* biostrome (see Raasch, 1954) which occurs about 500 feet above the base of the Etherington formation, and 90 feet below the base of the Rocky Mountain formation. A prolonged search, however, over and around this reef, failed to find the species in place.

Description.—The following description is based upon the holotype, a fragment of a corallum:

Transverse Section: Corallites are approximately equidimensional with an average diameter of about 7 mm. and corresponding tabularium width of about 5 mm. Intercepts are common in the dissepimentarium. Usually 20 to 22 major septa extend three-quarters of the distance to the center and reach or nearly touch the columella. Minor septa are about a quarter or less the length of the majors. The columella is very prominent. It is solid, usually circular or oval, and has a diameter varying between 1 and 2 mm.

Longitudinal Section: A good section was obtained only on an 8 mm. diameter corallite having a dissepimentarium width of about 2 mm. Dissepiments slope downward at a vertical angle of 45 degrees or more and are rather variable in pattern. They may be very small and vesicular, giving numerous rows of dissepiments to the dissepimentarium, or more commonly they are very elongate and narrow imparting an obliquely foliated appearance. Tabulae are closely spaced, about 20 in 5 mm. They extend across the dissepimentarium nearly flat or gently concave upward with little or no marginal deflection. The columella is a thick, solid rod about 1.5 mm. wide.

The paratype is very similar to the holotype. Longitudinal sections of the dissepimentarium are better preserved and show much the same dissepimental pattern as in the holotype. Where dissepiments are elongated usually 10 occur in a vertical distance of 5 mm. If measured at right angles to their inclination, however, between 15 and 20 would occur in the same distance. A few dissepiments were observed to be larger and have the more openly vesicular pattern observed on other species of *Lithostrotionella*.

Discussion.—The species is named in honor of Dr. C. R. Stelck of the University of Alberta.

Lithostrotionella stelcki differs from most species in possessing a very prominent thickened columella. This type of columella is known in the Permian species *L. occidentalis* (Merriam) and *L. berthiaumi* (Merriam). *Lithostrotionella stelcki* differs from the former in possessing well developed tabulae and from the latter in having nearly horizontal tabulae.

So far as known *L. stelcki* is the first species of this genus found in strata higher than the Mount Head formation in the Canadian Rockies. Although very rare it may perhaps be a good indicator for beds of upper Etherington age.

Genus LITHOSTROTION Fleming
LITHOSTROTION MUTABILE (Kelly)
Pl. 24, figs. 1–3

Diphyphyllum mutabile Kelly, 1942, p. 358, pl. 51, figs. 7,8.
Lithostrotion mutabile (Kelly). Crickmay, 1955, p. 12.
(?) *Lithostrotion* (*Diphyphyllum*) aff. *mutabile* Kelly. Sutherland, 1958, p. 96, pl. 33, figs. 2a,b.

Horizon and Locality.—Diagnostic for strata correlating with the upper part of the upper member of type Banff (upper Shunda formation) and the lower 200 feet of type Rundle.

Holotype, G.S.C. No. 9642: from "southwest slope of the mountain northwest of junction of McLeod River with Whitehorse Creek" (Kelly, 1942).
Hypotype, U. of A. No. 341: from rubble of the lower Rundle, South Ram River, Alberta (Lat. 51° 58′, Long. 116° 07′).

Description.—Transverse details of the holotype have been excellently described by Kelly. A cut longitudinal section of this specimen, however, shows three features not noted by him. The first is that a columella is present; the second that development of dissepiments is sporadic; and the third that tabulae are bent much more steeply downward at their outer margins than was indicated by Kelly's longitudinal thin-section. This thin-section is probably off-center so it does not show the first or third feature. Tabulae in the holotype are near horizontal or slope very gently upward over most of the corallite interiors and are commonly deflected slightly upward at the columella.

Near their outer margins they are strongly deflected downward, with the deflected portion extending down for a distance equivalent to the spacing of 2 to 3 tabulae before joining the dissepimental wall. If a dissepimentarium is absent they commonly become flatter near the thecal wall giving the deflected portion (in longitudinal section) a concave upward and outward profile. Hypotype U. of A. No. 341 shows the longitudinal features characteristic of the species.

Discussion.—The lower Mount Head species *Lithostrotion warreni* n. sp. has commonly been identified as *L. mutabile*. The two appear very similar in transverse sections but the latter has longer minor septa. Indeed some specimens have minors almost as long as majors. The two species can be rather easily distinguished in longitudinal sections. The tabulae of *L. mutabile* are deflected downward very sharply at their outer margins whereas those of *L. warreni* deflect downward relatively gently or not at all. Another criterion, which should only be used after numerous corallites have been examined, is that the tabulae of the former species are generally near horizontal while those of *L. warreni* are usually gently inclined upward to the columella.

LITHOSTROTION SINUOSUM (Kelly)
Pl. 24, figs. 4–10

Lithostrotion flexuosum Warren, 1927, p. 47, pl. 3, fig 7; pl. 6, fig. 2.
Diphyphyllum sinuousum (n. name) Kelly, 1942, p. 358.
Lithostrotion (Diphyphyllum) sinuosum (Kelly). Bassler, 1950, p. 221.
Lithostrotion sinuosum (Kelly). Crickmay, 1955, p. 12.
(?) *Lithostrotion* cf. *pauciradiale* (McCoy). Sutherland, 1958, p. 92, pl. 32, figs. 1,2,3a–c.

Horizon and Locality.—The stratigraphic range of this species is not yet certainly known. Based on occurrences from near the international border to the Banff area it is thought that the probable range is through the upper 400 feet of the Livingstone formation, as exposed at Tunnel Mountain. The upper limits of this species are probably in basal Mount Head strata (see discussion).

Holotype, G.S.C. No. 8913, 8913a: from "upper beds of Rundle limestone on Tunnel Mountain," Alberta (Warren, 1927) (probably basal Mount Head formation).
Hypotype, U. of A. No. 342: between 1175 and 1182 feet above the base of the Rundle, Tunnel Mountain, Alberta.
Hypotype, U. of A. No. 343: basal Mount Head formation, Upper Lodgepole River, British Columbia.

Description.—The holotype consists of three specimens (from one corallum) and a transverse and longitudinal thin section. Transverse details are well preserved on the polished surfaces and in the section. Longitudinal details, however, are well shown only in the thin section.

Transverse Section: Corallites are fasciculate, generally spaced from one to one and a half diameters apart, although occasionally in contact, and have an average diameter of 4½ mm. Usually 16 thin major septa extend about half the distance to the center. Minor septa are a third to a fourth the length of the majors and do not extend beyond the tabularium wall. The columella is very thin, but appears compressed-almond shaped because of secondary deposits. It is formed by extension of the counter septum.

Longitudinal Section: The only good section is on a 3¾ mm. diameter corallite having a dissepimentarium width of ⅓ to ¼ mm. Dissepiments are vertical, arranged in a single row, are generally oblong to compressed-oval, with between 10 and 15 occurring in a vertical distance of 5 mm. About 10 tabulae occur in the same interval. They have a rough sigmoidal curvature tending to steepen near the tabularium wall and columella. They are often incomplete, particularly toward the latter structure. The overall slope from the wall to columella varies between 30 and 45 degrees to the horizontal.

Discussion.—The present writer has made an intensive effort to find topotypes of this species but has failed. According to Dr. P. S. Warren (personal communication) the type locality is probably in basal Mount Head strata.

LITHOSTROTION WARRENI n. sp.
Pl. 24, figs. 11–14

Lithostrotion (Diphyphyllum) sp. A. Sutherland, 1958, p. 98, pl. 32, figs. 4a–d.

Horizon and Locality.—Lower Mount Head formation, ranging from the lower to the upper *Lithostrotionella* beds.

Holotype, U. of A. No. 338: 10 feet above base of Mount Head formation, Mount Rae, Alberta.

Description.—The following description is

based upon the holotype, a fragment of a corallum:

Transverse Section: Corallites are fasciculate, spaced one-half to a full diameter apart and have an average diameter of 6 mm. Usually 22 thinly wedge-shaped major septa extend one-half to one-third the distance to the center. Minor septa are short: one-third to one-fourth the length of the majors and commonly not extending beyond the dissepimental wall. The columella is almond-shaped.

Longitudinal Section: The dissepimentarium is about ½ mm. wide, in a 6 mm. diameter corallite, and consists of a single row of subglobose dissepiments, 8 of which usually occur in a vertical distance of 5 mm. Tabulae are rather variably spaced but generally 7 occur in the same distance. Typically they extend upward to the columella at a horizontal angle of between 20 and 30 degrees and join it with little or no upward deflection. They are usually bent downward near the outer margin of the tabularium, although some show no deflection. The columella is well developed and appears rod-like.

Discussion.—The species is named in honor of Dr. P. S. Warren, Professor Emeritus, University of Alberta.

LITHOSTROTION GENEVIEVENSIS Easton
Pl. 25, figs. 11–13

Lithostrotion (*Siphonodendron*) *genevievensis* Easton, 1957, p. 616, pl. 71, figs. 5–12 (gives complete synonymy).

Horizon and Locality.—Lower Etherington formation: the species is rare, but so far as known is restricted to beds coeval with those occurring between 100 and 140 feet above the base of this formation on Mount Rae, Alberta. The primary types are from the Ste. Genevieve limestone of Ohio River Valley, U. S. A.

Hypotype, U. of A. No. 344: 160 feet above base of Etherington formation, Mount Darrah, British Columbia.

Discussion.—Alberta specimens of *L. genevievensis* have occasionally been identified as *L. sinuosum* (Kelly) (see Raasch, 1954). They differ from the latter in having larger and more irregular dissepiments and flatter tabulae.

LITHOSTROTION (?) MACOUNI Lambe
Pl. 23, figs. 1,2

Lithostrotion macouni Lambe, 1899, p. 220.
Lithostrotion macouni Lambe. Lambe, 1901, p. 176, pl. 14, figs. 11,11a,b.
Lithostrotion sp. McLaren & Sutherland, 1949, p. 631, pl. 103, figs. 1–9, text figs. 2–4.
Lithostrotion macouni Lambe. Sutherland, 1958, p. 94.
(?) *Lithostrotion* (*Lithostrotionella*) (*Thysanophyllum*) *mclareni* Sutherland, 1958, p. 95, pl. 33, figs. 1a–g.

Horizon and Locality.—Horizon unknown. The only specimens known (Syntypes, G.S.C. Nos. 4327, 4327a, 4327b) are from "Fossil Point, Peace River, British Columbia."

Remarks.—The species is represented by three syntypes. Syntype No. 4327 has been thin-sectioned, both transversely and longitudinally. Syntypes No. 4327a and 4327b are not sectioned but are polished longitudinally.

Description.—The following is based upon syntype No. 4327. It is a fragment of a corallum having corallites weathering in a basaltiform pattern and showing very little increase in diameter along their lengths.

Transverse Section: Corallites are approximately equidimensional with an average width of 3 mm. and corresponding tabularium diameter of about 2 mm. Major septa are very thin, number between 10 and 11, and extend from the thecal wall to the center. Occasionally they are discontinuous in the dissepimentarium imparting a sublonsdaleoid appearance to some corallites. Minor septa are usually absent; if present they extend over about half the width of the dissepimentarium. The columella is not well preserved. It appears very thin and fragile.

Longitudinal Section: The thin section is apparently off-center so that axial details are not known. The dissepimentarium consists of a single row of unusually even sized sub-globose to subquadrate dissepiments, 13 to 15 of which occur in a vertical interval of 5 mm. Each dissepiment extends across the dissepimentarium as near horizontal or slightly convex upward curving downward, becoming near vertical near the tabularium wall and extending down to join the upper and inner surface of the preceding dissepiment. About 15 tabulae occur in 5 mm. Most extend upward from the tabularium wall at a horizontal angle of about 20 degrees and presumably would join the columella with little or no deflection.

Longitudinal polished sections of the other syntypes give no information on tabulae-columella relationships.

Discussion.—The species is questionably referred to *Lithostrotion* because of the sublonsdaleoid dissepimentarium which sometimes develops. If it does belong here then it is the first cerioid representative of the genus

from the Canadian Rockies known to the writer.

Lithostrotionella micra may be conspecific with *Lithostrotion* (?) *macouni*. The latter has smaller corallites, simpler tabulae and in most transverse sections a lithostrotionoid dissepimentarium.

The *Lithostrotion whitneyi* Group of Corals

Two distinct species, based mainly on tabular pattern, are distinguished among Mount Head corals hitherto referred to *Lithostrotion whitneyi*. These are here called *L. whitneyi* Meek and *L. arizelum* (Crickmay), respectively.

Lithostrotion whitneyi is characteristic of middle and upper Mount Head (as exposed on Mount Rae), ranging from the upper *Lithostrotionella* beds to near the top of the formation. Mature corallites vary from 9 to 12 mm. in diameter and have 25 to 32 amplexoid major septa. The dissepimentarium usually has 2 or 3 (rarely 4) rows of small globose dissepiments. Tabulae are diagnostic: they are nearly horizontal or gently inclined upward, and usually deflected upward and downward at the columella and tabularium wall, respectively.

Transversely *Lithostrotion arizelum* is similar to *L. whitneyi* although corallites are generally larger (15 to 20 mm.), and have more major septa (36 to 42). Longitudinal details are diagnostic: 4 or more rows of dissepiments are present and, most important, tabulae are steeply inclined upward. Uncertainty exists as to the stratigraphic interpretation of this species. The holotype occurs in basal Mount Head strata at Lake Minnewanka, the only locality where it is known to occur at this horizon. The other, relatively more widespread specimens referred to this species occur in uppermost Mount Head, as exposed at Mount Rae. It is thought that the latter *L. arizelum* may be a recurrent homeomorph developing out of *L. whitneyi* because of the similarity in tabular pattern between mature *L. whitneyi* and immature upper Mount Head *L. arizelum* (compare figures 2,4 and 8, plate 25).

Crickmay (1955, p. 11) has suggested that *L. whitneyi* and *L. arizelum* belong in the genus *Koninckophyllum* because of their numerous dissepiments and weak cardinal fossula. Specimens studied by the present writer, as well as those illustrated by Kelly (1942) and Parks (1951) usually show a very weak, almost unnoticeable fossula. Dissepiments, however, are not so numerous as in typical representatives of *Koninckophyllum*. Thus the writer is of the opinion that these two species are better placed in *Lithostrotion*.

LITHOSTROTION WHITNEYI Meek
Pl. 25, figs. 1–4

Lithostrotion whitneyi Meek, 1877, p. 58, pl. 6, figs. 1,1a–c.
(?) *Lithostrotion whitneyi* Meek. Kelly, 1942, p. 359, pl. 51, figs. 2,5.
Lithostrotion whitneyi Meek. Parks, 1951, p. 180, pl. 33, figs. 3,5.
Lithostrotion cf. *whitneyi* Meek. Sutherland, 1958, p. 93, pl. 31, fig. 3.
(?) *Lithostrotion* (*Diphyphyllum*) aff. *proliferum* (Thompson and Nicholson). Sutherland, 1958, p. 97, pl. 32, fig. 5.

Horizon and Locality.—Middle and Upper Mount Head formation, ranging from the upper *Lithostrotionella* beds upward for about 250 feet (as exposed at Mount Rae, Alberta).

Hypotype, U. of A. No. 323: between 145 and 153 feet above the base of the formation (upper *Lithostrotionella* beds), Mount Rae, Alberta.
Hypotype, U. of A. No. 345: 410 feet above base of formation, Mount Norquay, Alberta.

Description.—The following description is based on hypotype No. 323:

Transverse Section: Corallites tend to be evenly spaced a half diameter apart. They are of nearly equal size and have an average mature diameter of about 9 mm. Generally 25 to 27 very thin major septa extend two-thirds the distance to the center. Minor septa, about a third the length of the majors, usually just barely extend inward from the tabularium wall. The columella appears formed by extension of the counter septum and is usually very thin or slightly almond-shaped.

Longitudinal Section: Where the corallite diameter is about 9 mm., the dissepimentarium is about 1 mm. wide and consists of one, or more commonly two rows of dissepiments. Dissepiments are small, vesicular and are steeply inclined to near vertical, with 6 to 10 occurring in a vertical distance of 5 mm. About 10 tabulae occur in the same interval. They either leave the tabularium wall as near horizontal and steepen to a horizontal angle of about 20 degrees about half way to the columella, or extend across the tabularium with a horizontal angle of about 20 degrees, without noticeable steepening near the columella.

Tabulae are often incomplete, particularly at their outer margins and are commonly deflected downward there.

Hypotype, U. of A. No. 345 is similar to hypotype No. 323 but has larger corallites and more major septa. Diameters vary between 10 and 12 mm.; 32 major septa are present.

Discussion.—This species, as described and illustrated by Meek, consists of fasciculate corals with mature corallites usually not larger than 10 mm. Between 24 and 33 major septa either extend to the center or part way to it. Generally one row of vesicular dissepiments are present. Tabulae are nearly horizontal or gently inclined upward over most of the tabularium, steepening near the columella.

The hypotypes are close to Meek's specimens in corallite size and tabular pattern. Meek noted that the septa may or may not extend to the center. All septa are amplexoid in the hypotypes. The specific designation of the Mount Head specimens referred here should be treated with considerable caution. In the writer's opinion a complete redescription of the primary types or topotypes is desirable.

LITHOSTROTION ARIZELUM (Crickmay)
Pl. 25, figs. 5–10

Koninckophyllum arizelum Crickmay, 1955, p. 11, pl. 1, figs. 5,7.

Horizon and Locality.—Rare in the lowest beds of the Mount Head formation (known only from Lake Minnewanka). Homeomorphs (?) are characteristic of the uppermost part of the formation, as exposed on Mount Rae.

Holotype (Crickmay collection, Calgary), and portion of holotype (U. of A. Cb. 563): Crickmay's (1955) bed 14, section 2, Rundle of Lake Minnewanka, Alberta.

Hypotype, U. of A. No. 326: 490 feet above base of Mount Head (30 feet below top), Mount Rae, Alberta.

Hypotype, U. of A. No. 327: top of Mount Head formation at 4530 feet, fault slice 4 of Rundle, Crowsnest Pass, Alberta (see Nelson, 1959).

Description.—The following transverse description is based upon a portion of the holotype presented by Dr. C. H. Crickmay (labeled Cb. 563 in the University of Alberta collections). This specimen shows few longitudinal details because it is from the upper surface of a corallum. Consequently description of longitudinal structures is based upon another more complete specimen (topotype, U. of A. No. 325).

Transverse Section: Corallites are variable in size but usually range in diameter from between 12 to 20 mm. They are closely but rather irregularly spaced; generally a half or less their diameters apart. In a 12 mm. diameter corallite usually 27 major septa are present and extend about three-quarters the distance to the center. Minor septa are short, about a fifth or less the length of the majors. The counter septum is elongated and appears to form a rather simple vermiform columella. Where the corallite diameter is about 16 mm., 30 major septa extend three-quarters or more the distance to the center. They are very thin in the dissepimentarium but slightly dilated in the tabularium. Minor septa, about a sixth of the length of the majors, are confined to the dissepimentarium. As in immature corallites the counter septum is elongated to form the columella but the latter is surrounded by a few irregularly arranged structures, probably tabular intercepts. details of corallites greater than 16 mm. are not known.

Longitudinal Section: Longitudinal details are from a 14 mm. diameter corallite. The dissepimentarium is about 2 mm. wide and has four rows of steeply inclined, small vesicular dissepiments, 4 or 5 of which occur in a vertical distance of 5 mm. Tabulae are thin and generally 7 occur in the same interval. They are often incomplete, particularly toward the tabularium wall. Some are nearly horizontal over most of the tabularium and steeply bent upward near the columella, rising a distance equivalent to the spacing of 3 to 4 tabulae. Most extend from the tabularium wall with a horizontal angle of a little over 30 degrees and may or may not steepen near the columella. The latter appears simple and rod-like.

Most corallites have a calyx depth approximately equal to their diameters. The calyx appears flat-bottomed and has a small narrow conical boss formed by upturned tabulae. One 18 mm. corallite has a calyx at least 40 mm. deep. The type of preservation, however, suggests that the central structures may have been destroyed so as to give this deep appearance.

Hypotypes U. of A. Nos. 326 and 327, from the uppermost beds of the Mount Head formation are placed in this species. As noted previously, the writer considers them a recurrent homeomorph developing out of *L. whitneyi.* The following description is based on hypotype No. 326:

Transverse Section: Corallites are a half to a full diameter apart and have average mature diameters of about 15 mm. Where corallites are between 5 and 6 mm., 27 major septa extend about half

way to the center. Minor septa are about a quarter to a third the length of the majors and extend through most of the dissepimentarium. The columella is simple and compressed. Mature corallites generally have 36 major septa extending the same relative distance to the center. Minor septa are between a quarter to a fifth the length of the majors and do not usually extend inward from the tabularium wall. The columella appears simple and compressed.

Longitudinal Section: In a 7 mm. diameter corallite the dissepimentarium is about 1 mm. wide and has two rows of vertical, vesicular dissepiments, usually 7 of which occur in a vertical distance of 5 mm. Tabulae are relatively widely spaced: between 5 and 6 occur in the same interval. They are fairly gently inclined. Most leave the tabularium wall with a horizontal angle of between 10 and 30 degrees and join the columella with little deflection.

In mature corallites the dissepimentarium is about 2 mm. wide and has 3 or 4 rows of small steeply inclined, vesicular dissepiments, 5 or 6 of which occur in a vertical distance of 5 mm. Usually 7 to 8 steeply inclined tabulae occur in the same interval. They leave the tabularium wall with a horizontal angle of about 30 degrees and often steepen to one of 45 degrees or more, about two-thirds of the distance to the columella.

Hypotype U. of A. No. 327 suggests a further stage in the development of the *L. arizelum* homeomorphs in that corallites may grow up to 20 mm. in diameter, have 42 major septa and very steeply inclined tabulae. Tabular inclination apparently increases with corallite size.

Discussion.—Lithostrotion arizelum may be conspecific with the St. Louis species *L. proliferum* Hall. According to Kelly (1942, p. 359) the columella of the latter is made by upturned tabulae. In *L. arizelum* the columella appears formed by septa.

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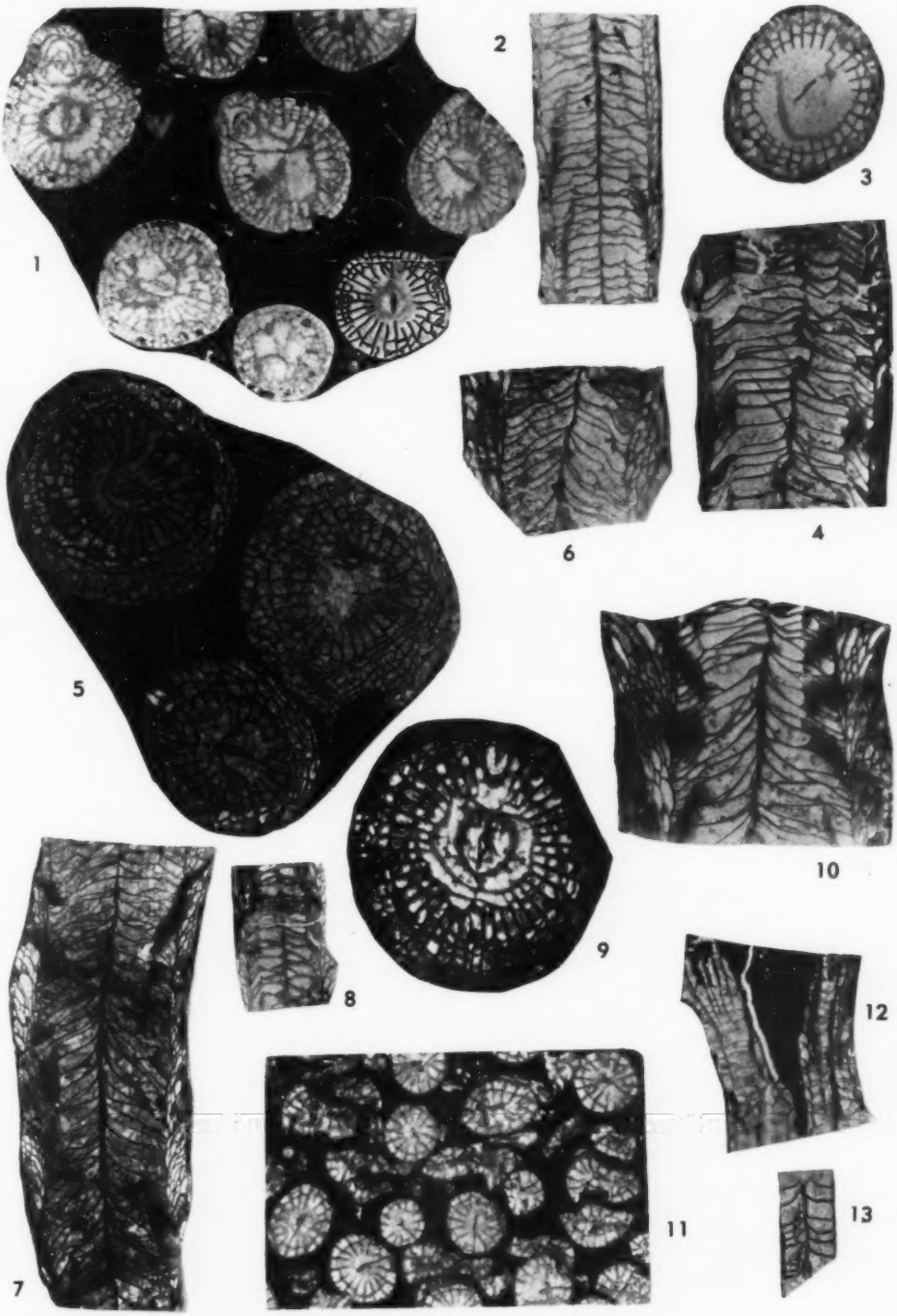
EXPLANATION OF PLATE 25

FIGS. *1–4—Lithostrotion whitneyi* Meek. Transverse and longitudinal sections, ×2. *1,2*, hypotype U. of A. No. 323; *3,4*, hypotype U. of A. No. 345.

5–10—Lithostrotion arizelum (Crickmay). Transverse and longitudinal sections, ×2. *5*, portion of holotype U. of A. No. Cb. 563; *6*, topotype U. of A. No. 325; *7,8*, hypotype U. of A. No. 326; *9,10*, hypotype U. of A. No. 327.

11–13—Lithostrotion genevievensis Easton. Hypotype U. of A. No. 344: transverse and longitudinal sections, ×2.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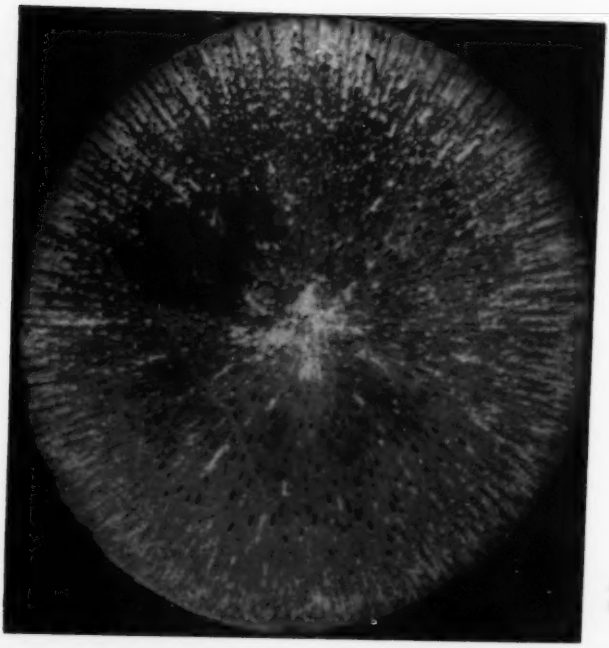

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HETERASTRIDIUM CONGLOBATUM CONGLOBATUM REUSS, AN UPPER TRIASSIC HYDROZOAN FROM THE PETRA-TOU-ROUMIOU LIMESTONE OF PENDAKOMO, CYPRUS

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ABSTRACT—The hydrozoan *Heterastridium conglobatum conglobatum* Reuss is described from the Petra-tou-Roumiou limestone of Southern Cyprus. The Pendakomo locality may be Carnic (?) or Noric in age, for *Heterastridium* is known only from these stages of the Tethyan Upper Triassic. A brief review of the distribution and stratigraphic range of *Heterastridium* Reuss and a glossary of the skeletal morphology is included.

INTRODUCTION

THE hydrozoan *Heterastridium* Reuss has been found widely distributed in the Upper Triassic of the Tethys. It is known from the Noric Hallstätter limestone at Salzkammergut and Salzburg, Austria (Reuss, 1865, p. 11, Frech, 1890, p. 95); from northern Italy (Terranini, 1958, p. 154); from a lower Noric limestone of Timor (Gerth, 1915, p. 66, 1944, p. 187); from the Noric stage of Hungary (Kutassy, 1930, p. 111, Kolosvary, 1954, p. 31); Bulgaria (Steinmann, 1893, p. 467); the Greek islands of the Sporades (Frech and C. Renz, 1908, p. 445); Persia (Douglas, 1929, p. 646); the Caracorum region (Duncan, 1879, p. 1, 1882, p. 70, 1892, p. 83; Oppenheim, 1907, p. 724; and Parona, 1928, p. 24); Alaska (Smith, 1927, p. 134). *Heterastridium* has been recorded from the Carnic stage of Hungary (Kutassy, 1930, p. 111) and the Caracorum (H. Renz, 1940, p. 69). Confined to the Carnic (*) and Noric stages of the Upper Triassic, yet with a wide horizontal distribution throughout the Tethyan successions, the genus is a good index fossil.

As originally described by Reuss (1865, p. 11), *Heterastridium* was a curious genus of Madreporaria. The hydrozoan nature of the organism was recognized by H. A. Nicholson (1889, p. 227), and F. Frech (1890, p. 94) and confirmed by all subsequent authors. Either or both *Syringosphaeria* and *Stoliczkaria*, two "Rhizopoda" described by P. M. Duncan (1879, p. 1) from the Upper Triassic of the Caracorum ("Caracorum stones"), were synonymized with *Heterastridium* Reuss by different authors.

The Triassic Petra-tou-Roumiou limestone unit as exposed in Southern Cyprus, consists of detached blocks of reef limestones lying haphazardly on the Mamonia limestone. Henson, et al. (1949, p. 11) favored the conclusion that the Petra-tou-Roumiou formation originally existed as a cap rock above the Mamonia deposits, that the overlying limestone was broken and locally baked by post-Triassic igneous extrusions and that the detached blocks now seen are residual rather than true exotics. Massive, pure white, crystalline reef limestone occurs at the type section at Petra-tou-Roumiou.

Some fossils have been determined by R. G. S. Hudson (see Henson, et al., 1949, p. 10): ? *Balatonia*, ? *Leiospongia*, *Montlival-*

* *Heterastridium* has been described by Kutassy, 1930, and H. Renz, 1940, from so-called Carnic limestones. According to Gerth, 1944, p. 184, the stratigraphic position of the Hungarian and Indian localities is uncertain.

EXPLANATION OF PLATE 26

FIGS. *1–2*—*Heterastridium conglobatum conglobatum* Reuss, from the Upper Triassic Petra-tou-Roumiou limestone of Pendakomo, Cyprus. All specimens figured are deposited in the collection of the Department of Palaeontology, British Museum (Natural History), London. *1*—H 4971. Polished section, showing some coenostea of different size. ×1.6. *2*—H 4971. Radial thin section showing closely set radial series and (dark) zooidal tubes. The zooidal tubes are conical-shaped and separated by coenenchymal structures. ×1.6.

tia cf. *M. timorica* Vinassa de Regny, *Stylophyllum* cf. *S. paradoxum* Frech, and *Thecosmilia* cf. *T. fenestrata* Reuss. The fauna was assigned to the Upper Triassic by Hudson.

Along the beach to the east of the Petratou-Roumiou rock, there are smaller boulders of reef limestones, highly indurated, silicified and discolored, evidently by contact with molten lava. These rocks yielded the following fauna determined by R. G. S. Hudson (in Henson et al., 1949, p. 10): Algae and hydrozoan debris, ? *Ceriopora*, *Disjectopora dubia* Vinassa de Regny, *Montlivaltia* cf. *M. marmorea* Frech, *Montlivaltia norica* Frech, sponge indet., ? *Stellispongia*, *Thecosmilia* cf. *T. cyathophylloides* Frech. Similar faunas occur, according to Muller (1936, p. 202) and Henson et al. (1949, pl 11), from the late Middle Triassic time almost to the close of the Triassic. Evidently the *Heterastridium* was found in these altered and discolored limestones; the material is red to brownish, partly silicified limestone, similar to the Hallstätter limestone facies.

The specimens of *Heterastridium* were found near the 39 mile post on the Nicosia-Limassol road, southeast of Pendakomo (see the Cyprus geological map by R. V. Browne and J. M. McGinty in Henson et al., 1949, pl. 1), approximately 1 mile southwest of the intersection of latitude 34°45′ N. and longitude 33°15′ E. All the specimens described are deposited in the collection of the Department of Palaeontology, British Museum (Natural History), London. Registration numbers H 4968 (2 pieces +1 slide), H 4970 (1 piece), H 4971 (2 pieces+1 slide).*

The author is indebted to Dr. H. Dighton Thomas of the Department of Palaeontology, British Museum (Natural History), for the loan of the Cypriotic material. Dr. H. Zapfe of the Geologisch—Palaeontologische Abteilung, Naturhistorisches Museum at Vienna, Austria and Dr. W. Freh of the Landesmuseum at Linz, Austria, made the original material of *Heterastridium conglobatum* Reuss available for comparison.

* The specimens have been recorded by H. D. Thomas in Ingham, F. J., 1956, Annual Report of the Geological Survey Department, Cyprus, for the year 1955, p. 6. (Personal communication of Dr. H. D. Thomas of the British Museum.)

SKELETAL MORPHOLOGY OF *HETERASTRIDIUM*

Methods of Investigation.—The Heterastridiidae described in this paper were investigated by the examination of transverse thin sections. The surface and form of the coenostea were also studied. The examination of the thin sections by stereoscopic microscope seems to be of little aid in distinguishing species of *Heterastridium*. All the slides I have seen of *Heterastridium* (from the Hallstätter limestone of Austria and from the Caracorum of Timor and Cyprus) exhibit a similar internal structure with nearly the same morphology. A discrimination of species by measurements of skeletal elements is made difficult by the fact that in most of the specimens the internal structure can be seen only in a small outer bordering zone; the interior of the coenostea is filled with crystalline substance or organic debris. The primary hollow ball may have been something like a swimming bladder of the colonies of the planktonic and pelagic Heterastridiidae. The form of the coenostea together with the sculpture of the surface allow a distinction of subspecies and variants (*"formae"*). Because there is a primary connection between the distribution of the internal skeletal structures and the *habitus* of the surface-sculpture, the description of the thin sections is important for the subspecific determination of the Heterastridiidae. For discussion of that taxonomic problem see E. Flügel and E. Sy (1959 p. 7).

DEFINITION OF MORPHOLOGICAL TERMS

Coenenchyme.—A vermiform structure consisting of bent radial elements (about 0.01 mm. thick) with nearly horizontal cross-beams of the same thickness. The largest part of the coenosteum is built up by the coenenchyme, which surrounds and separates the radial zooidal tubes. The coenenchyme may be differentiated into radial coenenchymal series. *Synonymous termini* for coenenchyme: Maschenwerk (*auct.*), Coenosarcal tissue (Nicholson)

Coenesteum.—The entire skeleton of Hydrozoa or a hydrozoan colony.

Radial series.—Radial bundles consisting of radially differentiated coenenchymal elements, recognizable as starlike structures built up by about 10 to 15 coenenchymal elements; observable in tangential sections. Most of the radial series end in elevations on the surface of

the coenosteum. *Synonymous termini* for radial series: Sternzellen (Reuss) Pfeiler (Frech), Coenenchym oder Radialbündel (Steinmann and others).

Skeletal tissue.—Using a magnification of ×60, a dark median line less than 0.01 mm. thick can be seen in the coenenchyme. This median line, which is bilateral in some cases, is arranged perpendicular in the radial coenenchymal elements and their horizontal crossbeams. The structure has been called "orthogonal" by Hudson (1958, p. 88). The Cypriotic material shows no median line, but the skeletal tissue has been altered by silicification. *Synonymous termini* for skeletal tissue: Mikro- oder Feinstruktur, Skelettfaser.

Surface.—The surface of the coenosteum may be covered with different kinds of elevations. These elevations are called papillae (=Wärzchen of Steinmann, 1893, p. 465), with the same diameter as that of the zooidal tubes; nodes (=Höcker of Steinmann), with a diameter 2 to 3 times that of the zooidal tubes; and monticuli (=Stacheln of Steinmann), large elevations, larger than the nodes, partly arranged in ranks.

Zooidal tubes.—Radially arranged tubes, about 0.50 mm. in diameter and 2 to 4 mm. long. Parts of the tubes are separated by the coenenchymal structures. In some coenostea ("*Stoliczkaria*") the zooidal tubes may be absent. Perhaps these tubes are the former living chambers of the polyps. *Synonymous termini* for zooidal tubes: Hohlräume (*auct.*), Röhren (Reuss), Gastroporen (Frech), Zooidröhren (Steinmann).

SYSTEMATIC PALEONTOLOGY

Classification.—The recent study of a Jurassic Hydrozoa by R. G. S. Hudson (1958, p. 90) gives a good summary of the problems which are associated with the systematics of fossil Hydrozoa. The long favored hypothesis that the Mesozoic Hydrozoa belong to the essentially Paleozoic order Stromatoporoidea has been opposed by Galloway and St. Jean (1957, p. 57–63). These authors consider that, on the basis of the tissue structure, only Paleozoic forms should be allocated to the Stromatoporoidea and the Mesozoic forms should be included in the Sphaeractinoidea. Hudson (1958, p. 90) considers the occurrence in both Paleozoic and Mesozoic forms of astrorhizal structures the most important diagnostic feature of both groups and justifies the inclusion in the Stromatoporoidea of those Mesozoic forms in which astrorhizae occur. Hudson recognizes the fundamental character of the difference in the microstructure of the skeletal tissue of Paleozoic and Jurassic-Cretaceous forms; he proposes a separation of Paleozoic and Mesozoic stromatoporoids into families.

The author has studied the Triassic Hydrozoa in a monographic work. There is no possibility to compare the Triassic Hydrozoa with the Stromatoporoidea. The Triassic Hydrozoa are separated by different skeletal tissue, different construction of the coenostea, and by lack of forms which lead from the Devonian Stromatoporoidea to the Carboniferous and Permian Hydrozoa. The astrorhizae were considered as a diagnostic feature not of some hydrozoan orders but of all the fossil Hydrozoa with a calcareous skeleton. Probably an intensive investigation of the astrorhizae and astrorhizoid structures of both Paleozoic and Mesozoic forms will throw some light on the phylogenetic significance of these structures; Schnorf-Steiner (1956, p. 567) has given interesting views on that problem.

On the basis of micro- and macrostructure the Triassic Hydrozoa were classified by the author as follows: Order Sphaeractinoidea Kühn with families Disjectoporidae Tornquist, Heterastridiidae Frech and Sphaeractinidae Waagen and Wentzel and the order Spongiomorphidea Alloiteau with the family Spongiomorphidae Frech. Forms comparable to stromatoporoids have not been found in the Triassic so far: probably the last genuine Stromatoporoidea are two species of the genus *Amphipora* described by Romanowsky (1890, p. 79) and Reed (1927, p. 180) from the Carboniferous.

Order SPHAERACTINOIDEA Kühn, 1927

Diagnosis.—Hydrozoa with a primary or secondary calcareous skeleton, composed of concentric and/or radial trabeculae or rods, with superposed galleries and differently developed astrorhizae. Skeletal tissue characterized by a variable clear dark median line which is enveloped by radially arranged or featherlike elements.

Remarks.—The above diagnosis is designed to include the following families and genera: the Permian and Triassic Disjectoporidae (genera *Carla*, *Disjectopora*, and *Irregulatopora*), the Permian to Cretaceous Sphaeractinidae (*Circopora*, *Ellipsactinia*, *Sphaeractinia*, *Plassenia*), and the Heterastridiidae (genus *Heterastridium*). All these

forms have a microstructure as described above. The Jurassic and Cretaceous family Stromatoporinidae may be included in the Sphaeractinoidea too; the type species of *Stromatoporina* Kühn, *Stromatopora tornquisti* Deninger, has a "fountainlike" microstructure. It seems evident that a great many of the Jurassic and Cretaceous Hydrozoa must be assigned as Sphaeractinoidea, but it is not considered advisable to propose a systematic scheme for these genera and families until more Mesozoic materials have been investigated by the author.

Family HETERASTRIDIIDAE Frech, 1890

Diagnosis.—Globular or ellipsoidal colonies, consisting of a vermiform texture, mostly with radially arranged zooidal tubes. Surface without, or with sculpture made by papillae, nodes or monticuli. Skeletal tissue orthogonal, but often destroyed by silicification.

Remarks.—Following O. Kühn (1939, p. A57) this family includes the genera *Stoliczkaria* Duncan, *Heterastridium* Reuss, *Cycloporidium* Parona, and *Parkeria* Carpenter. The author considers with G. Steinmann (1893, p. 467) that *Stoliczkaria* is only a *Heterastridium* without polyps (without zooidal tubes). "*Stoliczkaria*" seems to be the name of the nonreproductive part of the colony. Therefore *Heterastridium* and *Stoliczkaria* are identical. *Cycloporidium* Parona is a somewhat dubious Hydrozoa; described by Parona (1909, p. 157) from the Middle Cretaceous of Italy. The genus shows much similarity to some larger Foraminifera. *Parkeria* must be included in the Foraminifera, as stated by Carpenter himself (1870, p. 721) and recently by Hill and Wells (1956, p. F88).

Genus HETERASTRIDIUM Reuss, 1865

Type species.—(by original designation) *Heterastridium conglobatum* Reuss, lower Noric, Hallstätter limestone, Salzkammergut, Austria.

Diagnosis.—Globular, ellipsoidal or bipolar flattened colonies, composed of radially arranged zooidal tubes which are surrounded by supporting coenenchymal structure. The coenenchyme may be differentiated into radial series, which produce different kinds of elevations on the surface of the coenostea. Diameter of the globular colonies, between 15 mm. and 200 mm.

HETERASTRIDIUM CONGLOBATUM Reuss, 1865

HETERASTRIDIUM CONGLOBATUM CONGLOBATUM Reuss, 1865

Heterastridium conglobatum Reuss, 1865, p. 11, pl. 1, figs. 1–3, pl. 2, figs. 1–3, pl. 4, figs. 1, 2.

Heterastridium conglobatum conglobatum Reuss, in Flügel and Sy, 1959, p. 9, pl. 1, fig. 1. (with synonymy).

Lectotype (here chosen).—Specimen no. ½, described and figured by Reuss, 1865, pl. 1, figs. 1–3. Oberösterreichisches Landesmuseum Linz. From the lower Noric, Hallstätter limestone of the Sommeraukogel near Hallstatt, Oberösterreich, Austria.

Diagnosis.—Globular or ellipsoidal colonies without genuine surface sculpture, only small papillae. Internal structure regular, with zooidal tubes in regularly arranged radial series.

Description of Cypriotic material.—All the material—3 specimens—is from the Petratou-Roumiou limestone deposits southeast of Pendakomo, Cyprus. The limestone is altered partly by silicification. The rock samples studied are full of colonies of *Heterastridium* of very different size (diameter from 8 mm. to about 80 mm.). The samples may belong to a *Heterastridium* bank like the Heterastriidae of Timor, described by Gerth (1915, p. 64).

Specimen H 4968, pieces a and b, and thin section.—Coenosteum globular, diameter about 50 mm. Surface without sculpture, very small papillae only. The specimen has been cut in order to study the internal structure of the Hydrozoa by polished sections and slides. The slide shows the structure of the Hydrozoa only in about a 7 mm. broad outer zone; the interior of the coenosteum was filled with organic debris after death of the hydrozoan colony. The organic debris consists of fragments of Crinoidea, broken shells of small Gastropoda, and rarely, lagenoid Foraminifera. The coenosteum of the Hydrozoa is composed of a coenenchyme which is built of radially arranged, strongly bent elements, about 0.01 to 0.02 mm. thick. Real radial series are absent. Crossbeams

may enter between the radial elements. The zooidal tubes are of different lengths, averaging only 1 mm., and are not regularly superposed. Near the periphery, the horizontal distance between the tubes is about 1 mm.

Specimen H 4970, 1 piece.—Coenosteum globular, diameter about 80 mm. The surface of the colony is covered with fragments of attached smaller coenostea. No surface sculpture is to be seen.

Specimen H 4971, 2 pieces of 1 specimen, 1 slide (pl. 26, figs. 1,2).—The specimen is the most interesting one studied. It exhibits, on a polished surface, closely arranged colonies of different size (45 mm., 18 mm., 14 mm., and 8 mm. in diameter). The coenostea consist of closely set radial series, which are recognizable in the thin section by their intensive dark color. Diameter of the numerous zooidal tubes is about 0.9 mm. The tubes are closed by arched plates; the lower part of the zooidal tubes open into the coenenchymal zone. Lengths of the tubes are about 3.5 mm. The form of the tubes is like truncated cones with the apex against the peripheral zone of the colony. Partly the tubes are filled with dark brownish substance (pl. 26, fig. 2).

Remarks.—The Cypriotic specimens of *Heterastridium conglobatum* can be assigned to the subspecies *H. conglobatum conglobatum* due to the form of the coenostea. There is no special sculpture on the surface, therefore the specimens may be compared with the most frequent variety, *Heterastridium conglobatum conglobatum*, form *conglobatum*. This variety is characterized by the lack of greater elevations on the surface of the colonies and has been proposed by the author and E. Sy (1959, p. 9.)

Age and distribution.—The variety is known from the Carnic (? see footnote p. 127) and Noric stages of Europe, Asia and Alaska. Therefore, the Pendakomo locality is shown to be Carnic or Noric in age. If the recorded *Disjectopora dubia* Vinassa de Regny (Henson et al., 1949, p. 10) was found at the same locality another hint for age determination has been given: *Disjectopora dubia* was described from the Upper Triassic of Timor, and recorded from probable Noric limestones.

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SOME AMERICAN MIDCONTINENT CARBONIFEROUS CEPHALOPODS[1]

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ABSTRACT—Studies of Carboniferous cephalopods, principally from Arkansas but also from Kentucky, Indiana, Oklahoma, Texas, and Utah, have resulted in the recognition of six new genera: *Reticycloceras* (type species, *R. croneisi*, n. sp.) and *Mitorthoceras* (type species, *M. perfilosum*, n. sp.) which are orthoconic nautiloids, and *Paracravenoceras* (type species, *P. ozarkense*, n. sp.), *Fayettevillea* (type species, *F. planorbis*, n. sp.), *Pygmaeoceras* (type species, *Gastrioceras pygmaeum* Mather, 1915), and *Axinolobus* (type species, *A. modulus*, n. sp.) which are ammonoids. The following new names are also proposed: *Rayonnoceras foersti*, n. name for *R. vaughanianum*, Foerste and Teichert, 1930 [not *R. vaughanianum* Girty, 1909=*R. girtyi* Foerste and Teichert, 1930]; *Peripetoceras whitei*, n. name for *Nautilus missouriensis?* White, 1884 [not *N. missouriensis* Swallow, 1858]; *Coelogasteroceras coxi*, n. name for *Nautilus canaliculatus* Cox, April 1858 [not *N. canaliculatus* Eichwald, October 1857]; and *Neoglyphioceras hyatti*, n. name for *Gastrioceras entogonum* (Gabb)? Hyatt, 1891 [not *Goniatites entogonus* Gabb, 1862]. Lectotypes are selected for *Cravenoceras incisum* (Hyatt) [=*Glyphioceras incisum* Hyatt, 1893], for *Paracravenoceras barnettense* (Plummer and Scott)[=*Nuculoceras barnettense* Plummer and Scott, 1937=*Goniatites choctawensis barnettensis* Miller and Youngquist, 1948], and for *Pygmaeoceras pygmaeum* (Mather) [=*Gastrioceras pygmaeum* Mather, 1915].

INTRODUCTION

THIS paper is the by-product of a detailed study which the writer began a number of years ago of the Carboniferous cephalopods of Arkansas. Several new genera are being described here in advance of a more complete report in order that they may be made available at an earlier date to students of late Paleozoic cephalopods. These are *Reticycloceras*, *Mitorthoceras*, *Paracravenoceras*, *Fayettevillea*, *Pygmaeoceras*, and *Axinolobus*.

In addition, action is taken here on taxonomic problems involving six previously described species from other areas in the United States that were studied in connection with the Arkansas study. New names are proposed for four of these species, three to replace misidentifications and the fourth to relieve a homonymy. Three lectotypes are designated in order to establish early names more firmly.

Hyatt's specimens of *Glyphioceras incisum* Hyatt and *Gastrioceras entogonum* Gabb?, collected from what is now known as the Barnett formation of Texas, were borrowed from the University of Texas through W. C. Bell. The original lot of *Nuculoceras barnettense* Plummer and Scott, from the same formation, was obtained for study from the University of Texas Bureau of Economic Geology through J. T. Lonsdale. Most of the remaining previously described material studied is in the collection of the U. S. National Museum and was made available by G. A. Cooper. To those who have assisted this study the writer expresses thanks.

U. S. Geological Survey locality numbers are in two different registers. Numbers in roman type refer to the current Upper Paleozoic register (blue paper labels). Numbers in italics refer to an older register, no longer in use (green paper labels). U. S. National Museum numbers are preceded by USNM.

Genus RAYONNOCERAS Croneis, 1926

RAYONNOCERAS FOERSTEI, n. name

Pl. 27, fig. 5

Rayonnoceras vaughanianum Girty. FOERSTE & TEICHERT, 1930, p. 262, 263, pl. 48, fig. 1 [not GIRTY, 1909].

This name is proposed for the species mistakenly described and illustrated by Foerste and Teichert (1930, p. 262), as *R. vaughanianum* Girty. The incomplete phragmocone

[1] Publication authorized by the Director, U. S. Geological Survey.

to which, in the same paper (p. 262), they gave the name *Rayonnoceras girtyi* Foerste and Teichert, n. sp., actually is conspecific with *R. vaughanianum* Girty, as has been determined by a direct comparison of the two holotypes in the U. S. National Museum. The position of the siphuncle and the proportions of the siphuncular segments are identical in two specimens. In *R. vaughanianum* the siphuncle is subcentral, the connecting rings less than one-half as long as wide and there are 6½ camerae in a length equal to the diameter of the conch.

In *R. foerstei* the siphuncle is moderately excentric, the connecting rings are about five-eighths as long as they are wide, and approximately five camerae occur in a length equal to the diameter of the conch. This species has been described in some detail in the reference given above. The second specimen referred to *R. "vaughanianum"* by Foerste and Teichert (1930, p. 263), from Johns Valley, Oklahoma is also included in *R. foerstei* and is designated a paratype.

This species is perhaps closest to *R. fayettevillense* Croneis from which it differs principally in its less strongly excentric siphuncle, the proportions of the connecting rings being similar.

Holotype.—USNM 82217. Paratype, USNM 82218.

Occurrence.—Hill on east side of Oil Spring crossing of Hickory Creek, in the Arbuckle Mountain area, Oklahoma; from boulders in the Caney shale (the type is silicified throughout). The paratype is from Johns Valley, Ouachita Mountain area, Oklahoma.

Genus RETICYCLOCERAS Gordon, n. gen.
Cycloceras of authors [part].

Diagnosis.—Annulate orthoconic nautiloids with the earliest stage non-annulate and ornamented by fine transverse and longitudinal lirae to form a delicate network. Longitudinal lirae die out within two or three centimeters of the tip, but transverse lirae continue on through the body chamber. Siphuncle central to slightly excentric, suborthochoanitic to subcyrtochoanitic, pinched at the septal necks, which are abruptly recurved where complete; connecting rings subcylindrical, slightly convex to flat and faintly compressed at the middle and abruptly contracted at each end; siphuncular deposits continuous, heavier on ventral side; thick mural cameral deposits present.

Type species.—*Reticycloceras croneisi* Gordon, n. sp., described below.

Remarks.—Although the siphuncle is suborthochoanitic to subcyrtochoanitic and septal necks generally are not developed, the connecting rings are pinched in at either end, as in *Dolorthoceras*, and the siphuncular and cameral deposits are of the *Pseudorthoceras* type. This suggests the close alignment of the genus with the Pseudorthoceratidae.

Perigrammoceras Foerste is similar, but in that genus recurved septal necks are well developed and the apical end lacks the longitudinal threads of *Reticycloceras*. *Neocycloceras* Flower and Caster apparently has a cyrochoanitic siphuncle also, but its segments are nummuloidal. The siphuncle and apical end of the type species of *Cycloceras*, *Orthocera annularis* Fleming, 1815, are not known. Turner (written communication, 1954) has examined the holotype, and says it is an internal mold of the body chamber, showing nothing of the siphuncle or fine details of the external sculpture. He has not been successful in efforts to obtain better specimens.

Because over 140 years have elapsed since the type species was described and no better examples have turned up, the writer regards *Cycloceras* as a genus inquirendum and refers to it only the type species.

Species belonging in *Reticycloceras* include, beside the type species, *Cycloceras kionoforme* Demanet, 1941, *C. seguoyahense* Snider, 1915, and *Orthocera sulcata* Fleming, 1815 (as figured by Foord, 1888, p. 123, Text-fig. 9).

Distribution.—This genus appears to be limited to the upper part of the Upper Mississippian. It occurs in rocks of Chester age in Arkansas, Oklahoma, and Utah, and in rocks of Early Namurian (and possibly very late Viséan) age in England and Belgium.

RETICYCLOCERAS CRONEISI
Gordon, n. sp.
Pl. 27, figs. 9–11

Diagnosis.—*Reticycloceras* with the conch expanding 1 mm. in 7½ mm., approximately

circular in cross section, with a subcentral siphuncle; 3 to 3½ camerae and 2 to 4 annuli in a length equal to the dorsoventral diameter; transverse lirae fine and crowded in young shell, widely spaced in mature shell.

Description.—The holotype is part of a phragmocone, 22 mm. long, nearly circular (slight compression probably due to distortion after burial), 4 mm. in diameter at its apical end and 6.5 mm. at the oral end, expanding at a rate of 1 mm. in 7.6 mm. Annuli are inclined 75 to 78 degrees to the shell axis, bowed apicad on the ventral side. Septa are saucer shaped, shallow, and approximately at right angles to the shell axis.

The apical end of the shell (Pl. 27, fig. 11) is ornamented by roughly 50 to 60 fine longitudinal lirae that extend about a centimeter forward from the tip. These are crossed by fine transverse lirae spaced 14 in 1 mm., forming with the longitudinal lirae an exceedingly fine reticulation. Indistinct, low, rounded annuli begin near the end of the longitudinally lirate part of the conch. In more mature parts of the conch the annuli become higher and narrower and the interspaces broader. In the early parts of the of the shell interspaces are about 1½ times the width of the annuli and in the later parts they may reach 2½ times the width of the annuli. The transverse lirae become sparse within a half centimeter of the end of the longitudinally lirate part of the conch. From here on the conch is ornamented by fairly coarse transverse threads, 6 to 9 occurring between crests of adjacent annuli, gradually increasing to 15 to 20 in the later parts of the conch. Some fine lirae occur between the coarser threads.

The siphuncle is subcentral, subcyrtochoanitic, with subcylindrical connecting rings. At its widest part it is one-fifth as wide as the conch, but between the septal necks it is only one-tenth as wide. The septal necks in a cross section are strongly recurved, the septal brims nearly straight and almost as long as the area of adnation is wide. This section does not show a strong siphuncular deposit as in other shells of the genus, but there appear to be remnants of a siphuncular deposit on one side of the shell which have become recrystallized into granular calcite. Lamellar mural deposits are thickly developed in the camerae. They are thickest on the ventral side of the conch and are progressively thinner dorsad.

Reticycloceras croneisi is distinguished from the closely related *R. sequoyahense* (Snider) by the longer camerae, more widely spaced annuli, and coarser transverse sculpture in the adult conch.

Primary types.—Holotype, USNM 11929. Paratypes, USNM 119030–34, inclusive, and 119068.

Occurrence.—Pitkin limestone, upper shale member, USGS localities 15058 (paratype), 15060 (holotype and 7 paratypes), 15062 (7 paratypes) in the NE¼ sec. 2, T. 13 N., R. 9 W. about ½ mile southeast of the Jim Davis place, 2 miles south of Pleasant Grove, Stone County, Arkansas: 14369 (paratype), roadcut on southeast side of U. S. Highway 65, about ½ mile southwest of the bridge across Peyton Creek, Van Buren County, Arkansas. Fayetteville shale, upper shale member, USGS locality 15073 (paratype), on south slope of knoll capped by Pitkin limestone, 100 to 150 yards north of county road, 2½ miles east of Elkins, Washington County, Arkansas.

Genus MITORTHOCERAS Gordon, n. gen.

Diagnosis.—Small orthoconic nautiloids with the surface of the conch ornamented by raised transverse lirae, separated by concave to flat interspaces; these lirae usually are very gently sinuous. Septa of moderate concavity; sutures fairly straight and generally at right angles to the shell axis, though they may be inclined in some species. Siphuncle cyrtochoanitic, subcentral to moderately excentric, subcylindrical, slightly contracted at the septal necks, lines with annulosiphonate deposits that taper orad from the septal necks and generally merge with the succeeding deposits. Camerae contain strong lamellar episeptal deposits and weaker hyposeptal deposits, slightly thicker on the siphonal side of the conch.

Type species.—*Mitorthoceras perfilosum* Gordon, n. sp., described below.

Discussion.—These transversely lirate orthoceracones with dolorthoceroid siphuncles have been referred by previous authors most commonly to *Orthoceras*, *Mooreoceras*, or *Dolorthoceras*. These shells constitute an important element in American Mississippian faunas and are therefore accorded generic

rank here. Superficially they resemble shells of the genus *Bitaunioceras* Shimizu and Obata which may, however, be distinguished by its flatter asymmetric surface lirae and orthochoanitic siphuncle.

The oriented position of the siphuncle has been determined in another species referred to this genus, found associated with *Cravenoceras merriami* Youngquist in the Chainman shale (*Eumorphoceras bisulcatum* zone) in the Confusion Range, Utah (USGS loc. 17024). It is similar in sculpture and length of camerae to the type species but differs in having the septa inclined about 16 degrees ventrorad. Both the ventral furrow (conchial furrow of Flower, 1939, p. 12) and the dorsal furrow (septal furrow of Flower, 1939, p. 13) are preserved on the internal mold. The siphuncle, 1 mm. in diameter at the septum, is located one-sixth the way from center to dorsum.

Included here in *Mitorthoceras*, along with the type species, are *Orthoceras choctawense* Girty, 1909, *O. crebriliratum* Girty, 1909, *O. kildarense* Foord, 1896, and *Orthoceratites striolatus* von Meyer, 1831. Although the internal structures of *O. choctawense* Girty and *O. kildarense* Foord are not known, the shape of their shells and of their transverse lirae and the slightly excentric siphuncles strongly suggests that they belong in *Mitorthoceras*. Some of the transversely lirate shells from the Chouteau limestone of Missouri, described by Miller and Furnish (1938, p. 164–169) as *Mooreoceras*, may also belong in this genus.

Distribution.—*Mitorthoceras* ranges throughout the Mississippian and may be restricted to it. It has been found in beds from Kinderhook to late Chester in age. In the collections of the U. S. Geological Survey are specimens from Arkansas, Mississippi (subsurface), Oklahoma, Texas, Utah, California, and Alaska. The genus occurs also in the early Carboniferous of Ireland and in the Viséan (zone IIIβ) of Germany.

MITORTHOCERAS PERFILOSUM
Gordon, n. sp.
Pl. 27, figs. 1–4, 8

Orthoceras sp. GIRTY, 1909, p. 47.
Mooreoceras crebriliratum(Girty). MILLER & YOUNGQUIST, 1948, p. 653, pl. 94, figs. 4,5; MILLER, YOUNGQUIST, & NIELSEN, 1952, p. 152, pl. 25, figs. 10–16.

Diagnosis.—Conch orthoconic, expanding about 1 mm. in 12 mm., circular in cross section, the surface ornamented by closely spaced transverse lirae of which 6 or 7 occur in the space of one millimeter. Siphuncle excentric, subcylindrical, cyrtochoanitic but with very weakly recurved septal necks, its diameter about one-seventh that of the conch.

Description.—The holotype, part of a phragmocone 31 mm. long, has a diameter of 6.2 mm. at the narrow end and expands to 8.2 mm. at the wide end, in a distance of 23 mm. The surface sculpture is preserved over much of the specimen and consists of raised sharp rounded lirae with subequal to slightly wider interspaces. Twenty-nine of these lirae occur in the space of 5 mm. They are very gently sinuous and form a broad shallow orad bow across the siphonal side of the conch. The siphuncle, in the plane of the septum at the apical end of the specimen, has a diameter of 0.8 mm. and center is 2.2 mm. from the nearest edge of the conch—that is, about three-tenths of the distance from the center to the outer margin.

Longitudinal dorsoventral thin sections of paratypes show a range in spacing of the camerae from 1.5 to 2.1 per conch diameter, most of them approximately 1.8. The siphuncle is subcylindrical, slightly constricted at the septal necks. The slightly recurved septal necks indicate that it is of the cyrtochoanitic type. However, the curvature of the necks is somewhat variable and so gentle that the edges of the septa can hardly be said to be produced into brims. Siphuncular deposits are of the *Dolorthoceras* type, extending less than a millimeter apicad from the septal necks but tapering orad and generally in contact with the succeeding deposit. Those on the side of the siphuncle nearest the shell wall tend to be a little weaker and some do not reach the succeeding deposit.

The episeptal and hyposeptal cameral deposits are thick, irregularly lamellar, and normally fill all but a small space near the middle of the chamber. In some camerae hyposeptal deposits are not developed on the siphonal side of the conch.

Discussion.—The Arkansas paratype illustrated on Pl. 27, figs. 1,2 appears identical with the Utah types. Girty (1909, p.

47) described as *Orthoceras* sp. a specimen from the Caney shale of Oklahoma which, a reexamination shows, has 1½ camerae in the space of one diameter of the conch and surface sculpture of 6 transverse lirae in the space of one millimeter. This record is included in the synonymy of *M. perfilosum*. Conspecific also are specimens cited and figured as *Mooreoceras crebriliratum* (Girty) by Miller and Youngquist (1948) from the Barnett formation of Texas and by Miller, Youngquist, and Nielsen (1952) from the Chainman shale in the Confusion Range, Utah.

Mitorthoceras crebriliratum (Girty) differs from *M. perfilosum* in having finer, more delicate surface sculpture with 9 transverse lirae in the space of one millimeter and in having more strongly recurved septal necks and apparently less well developed cameral deposits.

Types.—Holotype, USNM 119050. Paratypes, USNM 119051, 30 specimens, 119052. 1 specimen.

Occurrence.—The type lot is from the Chainman shale (*Goniatites granosus* zone), USGS locality 14556, weathered from 20-foot section of dark-gray shale between two prominent limestone ledges, several yards east of dirt road along Chainman shale valley, 2½ miles south of Skunk Spring, Confusion Range, Millard County, Utah. The Arkansas paratype is from the Ruddell shale, middle part, USGS locality 9895, on southwest slope of Ruddell hill, 300 feet northwest of Cushman Junction switch, about 2½ miles west of Batesville, in the NE¼SE¼ sec. 13, T. 13 N., R. 7 W., Independence County, Arkansas. This species occurs also in the Caney shale of Oklahoma and the Barnett shale of Texas.

Genus PERIPETOCERAS Hyatt, 1894

PERIPETOCERAS WHITEI Gordon, n. name

Pl. 27, figs. 6,7

Nautilus missouriensis Swallow? WHITE, 1884, p. 166, pl. 35, figs. 1,2 [not *N. missouriensis* Swallow, 1858].

Nautilus missouriensis HYATT (?), 1893, p. 453; [part] KEYES, 1894, p. 224, pl. 56, fig. 3.

Coloceras missouriensis [part] MILLER, DUNBAR, & CONDRA, 1933, p. 131, 195; [part] MILLER & OWEN, 1934, p. 216,217.

This new name is proposed for the shell questionably identified by White (1884, p. 166, Pl. 35, figs. 1,2) as *Nautilus missouriensis* Swallow. As suggested by Miller and Owen (1934, p. 216) the shell originally described by Swallow (1858, p. 198) under this name, from near the base of the Coal Measures (Cherokee group) of Boone County, Missouri, probably belongs in the genus *Liroceras* Teichert, 1940 [= *Coloceras* Hyatt, 1893, not Nitzsch, 1882]. It was a small specimen, 0.65 inch in diameter. As it was never figured and was destroyed in the fire at the University of Missouri in 1892, we will never know to what species Swallow attached the name *N. missouriensis*.

White's shell, which was refigured by Keyes (1894, Pl. 56, fig. 3), is considerably larger than that of Swallow and belongs in the genus *Peripetoceras*. Of similar size are the Arkansas specimens described by Smith (1896, p. 42, Pl. 21, figs. 1–3) as *Endolobus* (*Nautilus*) *missouriensis* (Swallow). These, however, belong in *Stearoceras* and are being renamed and described in the writer's forthcoming Arkansas cephalopod paper.

White's shell, over 70 mm. in diameter, consists of a nearly complete phragmocone of approximately two volutions. To this is attached a short fragment of the body chamber of which, at the umbilical shoulder, about a centimeter of length is preserved. The conch is nautiliconic. The whorl is reniform in cross section, a little wider than high, with a well-rounded venter merging into less rounded umbilical walls. On the dorsal side an impressed zone of moderate depth is slightly over half as wide as the whorl. The greatest width of the whorl is approximately at the umbilical shoulder. The diameter of the umbilicus is approximately one-third that of the conch. The umbilicus shows the earlier volution within and is narrowly perforate, the perforation 3 to 4 mm. in diameter.

The septa are moderately concave orad and the sutures develop the typical sinuations of *Peripetoceras*. They are rather variable across the venter, either approximately straight or forming a very shallow moderately broad lobe. Broad well-rounded lobes occur on the flanks, with narrower gently rounded ventrolateral and dorsolateral saddles. The sutures curve gently apicad across the umbilical wall, apparently to

form a dorsal lobe, but the dorsum is concealed by the earlier whorl. As near as can be determined 19 camerae occur on the last volution of the phragmocone, the last two a little shorter than the preceding ones. The position of the siphuncle has not been determined.

Dimensions in mm. are as follows: diameter (D), 72; height of last whorl (H), 36; width of last whorl (W), 38.5; width of impressed zone, 21; diameter of umbilicus (U), 25. These give the following shell ratios: U/D=0.35, W/D=0.53, and W/H=1.07.

Holotype.—USNM 65822.

Occurrence.—Coal Measures, Fountain County, Indiana.

Genus COELOGASTEROCERAS Hyatt, 1893

COELOGASTEROCERAS COXI Gordon, n. name

Nautilus canaliculatus Cox, 1858, p. 575, pl. 10, figs. 3,3a [not *N. canaliculatus* Eichwald, 1857].
Solenoceras canaliculatum Hyatt, 1884, p. 286.
Coelogasteroceras canaliculatum Hyatt, 1893, p. 392,447,448; 1894, p. 498,499, pl. 10, fig. 33; Miller, Dunbar, & Condra, 1933, p. 213, pl. 14, figs. 1,2.

Nautilus canaliculatus Cox and *N. canaliculatus* Eichwald are homonyms. Cox's shell is the type species of *Coelogasteroceras* Hyatt, 1893. The problem has been to determine which is the junior homonym. The publication date of Cox's species has heretofore been taken as 1857, the date which appears on the title page of volume 3 of the Kentucky Geological Survey reports, in which Cox's paper appeared.

Eichwald (1860, p. 1314) in Lethaea Rossica attributed his species to Geognosie de Russie (Eichwald, 1846, p. 421), but in the earlier work *N. canaliculatus* is a *nomen nudum*, appearing only in a faunal list. The earliest description of this species I have been able to find is a brief diagnosis in the Cephalopod part of "Beitrag zur geographischen Verbreitung der fossilen Thiere Russlands" (Eichwald, 1857, p. 208) which appeared in volume 30, number 1 of the Bulletin of the Société Impériale des Naturlistes de Moscou, 1857. Because both Eichwald's and Cox's *Nautilus canaliculatus* were first described in publications in which the year 1857 appears as the publication date, it is necessary to determine with greater accuracy the actual date of publication.

The records of the Société Impériale des Naturalistes de Moscou (Bull., tome 31, no. 1, p. 311, 1858) for the meeting of October 17, 1857 state that on that occasion the First Secretary, Dr. Renard, presented Bulletin No. 1 and No. 2 for 1857, which had appeared under his editorship. This was a custom of long standing in the Society and the October meeting can be taken as the approximate date of publication of this work.

Volume 3 of the Kentucky Geological Survey reports does not appear to have come out as early. Part of the field and laboratory work included in this volume was done in 1857. The letter of transmittal to D. D. Owen accompanying Dr. Peter's chemical report which occupies 249 pages of the volume is dated September 14, 1857. This would have left little time for setting up, proofing, printing, and distributing the work in what remained of the year. Actually, this volume appears to have been distributed early in the Spring of 1858, probably in March or early April. In the May issue of the American Journal of Science (ser. 2, v. 25, n. 75, p. 446,447, 1858) a review of the Third Report of the Geological Survey in Kentucky stated, "In our last number (March, 1858) we noticed the publication of the second volume of the Kentucky Survey; and another two months have brought out a volume even larger, with ten plates of fossils." The Proceedings of the Philadelphia Academy of Sciences for 1858 (Donations to the library, p. vii, 1859) recorded receipt of their copy of the third Kentucky Survey report from the author as of April 13, 1858.

From this evidence it appears that *Nautilus canaliculatus* Eichwald has priority over *N. canaliculatus* Cox, which was originally designated as the type species of *Solenoceras* Hyatt, 1884 [not Conrad,1860], for which Hyatt (1893, p. 392) later proposed the new generic name *Coelogasteroceras*. As *N. canaliculatus* Cox was not based on a misidentification of *N. canaliculatus* Eichwald, the primary homonymy should be relieved. I therefore propose the name *Coelogasteroceras coxi*, n. name, to replace *Nautilus canaliculatus* Cox [not Eichwald].

Holotype.—Kentucky Geological Survey, not seen.

Occurrence.—Ferruginous bed of Early Pennsylvanian age, near Nolin Iron Works, Edmonson County, Kentucky.

Genus NEOGLYPHIOCERAS Brüning, 1923

In this genus the writer is including *Lyrogoniatites* Miller and Furnish, 1940, (type species, *L. newsomi georgiensis* Miller and Furnish, 1940) erected for the broader, more evolute forms of this longitudinally lirate group of goniatites. The typical form of *Neoglyphioceras* (type species, *Goniatites spiralis* Phillips, 1841) is compressed and rather involute. Intermediate forms are now known and as all of this group is found in a single major goniatite zone, the *Goniatites granosus* zone, there is probably no good reason for separating them. The species discussed below is the most widely umbilicate form known.

NEOGLYPHIOCERAS HYATTI Gordon, n. name
Pl. 28, figs. 22–24

Gastrioceras entogonum (Gabb)? HYATT, 1893, p. 472,473, pl. 47, figs. 49–51 [not *Goniatites entogonus* Gabb, 1862].
Gastrioceras entogonum SMITH [part], 1903, p. 87, pl. 10, figs. 17–19.
Neoglyphioceras entogonum PLUMMER & SCOTT, 1937, p. 186,187, pl. 9, figs. 1–3.
Lyrogoniatites entogonus MILLER & FURNISH, 1940, p. 368, Pl. 48, figs. 17,18.

This name is proposed for the species represented by the specimen questionably identified by Hyatt (1893, p. 472), as *Gastrioceras entogonum* (Gabb)?. Gabb's type appears to have been lost, but judging from his original description of *Goniatites entogonus* Gabb (1862, p. 372) it is different enough from Hyatt's shell to eliminate the possibility of the two being conspecific, or even congeneric. A comparison of the characters of the shell of Gabb's description with those of Hyatt's specimen are given in the table below.

A careful study of Gabb's original decription of *Goniatites entogonus* has convinced the writer that it could not possibly pertain to the same species as Hyatt's shell. Two possibilities for Gabb's shell suggest themselves—that it was a *Paralegoceras* or a *Pseudoparalegoceras*. *Paralegoceras* has a divided ventral lobe and two pairs of lateral lobes on the flanks. However, if the suture of *Pseudoparalegoceras* is reversed, as it was in the illustration accompanying the original description of *Gastrioceras compressum* Hyatt (1891, p. 355,356, Text-fig. 59) it is possible to recognize an undivided "ventral lobe" and two pair of lateral "lobes" that are in actuality saddles. This is not to imply that either Hyatt or Gabb made such a mistake, but to emphasize the fact that until Gabb's specimen is found, there is no way of assigning his species *Goniatites entogonus* with certainty to any known genus.

Hyatt's description of "*Gastrioceras entogonum* (Gabb)?" was based on a single specimen which is here designated the holotype of *Neoglyphioceras hyatti*. This shell (UT 12036) has been examined by the writer and is figured on Pl. 28, figs. 22–24. In addition to Hyatt's original figures (1893, Pl. 47, figs. 49–51), this same specimen has

Character	Gabb's original description of *Goniatites entogonus*	Hyatt's specimen of "*Gastrioceras entogonum*?"
Shape	Robust, discoidal	Thick-discoidal
Umbilicus	One-third the shell diameter	More than half the shell diameter
Umbilical shoulder	Angular	Angular
Growth constrictions	Five	Three or four
Longitudinal sculpture	Umbilical carina	17 cords
Diameter	67.2 mm.	36.7 mm.
Height of last whorl	22.9 mm.	12.3 mm.
Width of last whorl	30.5 mm.	20.2 mm.
Width of umbilicus	22.0 mm.	20.0 mm.
Umbilicus/diameter	.33	.55
Width/diameter	.45	.55
Width/height	1.33	1.64
Septa	Spaced so that sutures overlap	Sutures not preserved
Lobes of external suture	One ventral and two pair of lateral lobes	None preserved, but *Neoglyphioceras* has a shallowly divided ventral and one pair of lateral lobes

been illustrated as *Gastrioceras entogonum* (Gabb) by Smith (1903, Pl. 10, figs. 17,18), as *Neoglyphioceras entogonum* (Gabb) by Plummer and Scott (1937, Pl. 9, figs. 1–3), and as *Lyrogoniatites entogonus* (Gabb) by Miller and Furnish (1940, Pl. 48, figs. 17,18).

Holotype.—No. 12036, Univ. Texas collection.

Occurrence.—Barnett formation, bank of Espey Creek, 5 miles southwest of Lampasas, Lampasas County, Texas.

Genus CRAVENOCERAS Bisat, 1928

CRAVENOCERAS INCISUM (Hyatt)

Pl. 28, figs. 32–36; Text-figs.1 G,J,K

Glyphioceras incisum [part] HYATT, 1893, p. 471,472, pl. 47, figs. 44,45 [not figs. 46–48]; [part] SMITH, 1897, p. 111–121 [not pls. 13,14, 15].

Goniatites crenistria Phillips [part]. SMITH, 1903, p. 68–76. pl. 10, figs. 12,13 [not pl. 10, figs. 14–16, pl. 14, pl. 15, pl. 16, figs. 1a–j].

Nuculoceras incisum (Hyatt) [part]. PLUMMER & SCOTT, 1937, p. 106–108, pl. 7, figs. 7–9 [not figs. 10–14].

Cravenoceras hesperium Miller and Furnish? MILLER & YOUNGQUIST, 1948, p. 656, pl. 95, figs. 7–9,13–15.

Hyatt originally described *Glyphioceras incisum* from two specimens collected near Richland Springs, San Saba County, Texas. Examination of these specimens, borrowed from the University of Texas, shows that two species are represented. The larger one with matrix attached and showing surface sculpture, illustrated by Hyatt (1893) on plate 47, figures 46–48, belongs to the species that was later described as *Nuculoceras barnettense* Plummer and Scott. The other, a small loose specimen showing the suture, illustrated by Hyatt (1893) on plate 47, figures 44 and 45, is hereby designated as the lectotype of *Glyphioceras incisum* Hyatt. This same specimen was refigured by Plummer and Scott (1937, Pl. 7, figs. 7–9) and it is also figured in the present report (Pl. 28, figs. 32–36).

Cravenoceras incisum is a small species; none of the available specimens reaches 25 mm. in diameter. The conch is subglobose, with a well-rounded broad venter merging into rounded flanks and a slightly depressed umbilical area. One of the most characteristic features of this shell, seen in cross section (Text-fig. 1G,K), is the rather constant diameter of the umbilicus beyond the first three volutions of the shell. The surface of the test is ornamented by narrow transverse cravenocerid lamellae that remain nearly rectilinear during growth. Internal varices are spaced a third of a volution apart on the lectotype. The umbilical area is without longitudinal sculpture of any sort.

The suture is rather simple, of the cravenocerid type, the ventral lobe hardly wider than the first lateral saddle or first lateral lobe and divided to less than half its length by a blunt median saddle.

Dimensions and proportions are as follows.

	Hypotype	Lectotype
Diameter (D)	17.2 mm.	16.2 mm.
Height of last whorl (H)	8.9 mm.	7.7 mm.
Width of last whorl (W)	14.2 mm.	13.5 mm.
Diameter of umbilicus (U)	2.6 mm.	3.0 mm.
U/D	.15	.18
W/D	.83	.82
W/H	1.60	1.75

EXPLANATION OF PLATE 27

[Figures natural size except as otherwise indicated on plate]

FIGS. *1–4,8—Milorthoceras perfilosum* Gordon, n. gen., n. sp. *1,2.* Enlarged size and apicad views of a specimen, USNM 119052, from USGS locality 9895, Ruddell shale, Ruddell Hill, Independence County, Arkansas. *3,4,* Ventral and enlarged ventral views of the holotype, USNM 119050, from USGS locality 14566, Chainman shale, Confusion Range, Millard County, Utah. *8,* Ventrodorsal section of a paratype, USNM 119051, showing camerae, siphuncle and cameral and siphunclar deposits, from the same locality as the holotype.

5—Rayonnoceras foerstei Gordon, n. nom. Polished ventrodorsal section of the holotype, USNM 82217, Caney shale, hill on east side of Oil Spring Crossing, Hickory Creek, Oklahoma.

6,7—Peripetoceras whitei Gordon, n. nom. Rear and side views of the holotype, USNM 65822, Coal Measures, Fountain County, Indiana.

9–11—Reticycloceras croneisi Gordon, n. gen., n. sp. *9,10.* Side and enlarged side views of the holotype, USNM 119029, from USGS locality 15060, Pitkin limestone, upper shale member, 2 miles due south of Pleasant Grove, Stone County, Arkansas. *11,* Enlarged side view of the apical part of a paratype, USNM 119031, showing longitudinal lirae, from USGS locality 15062, approximately the same locality as the last.

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X5
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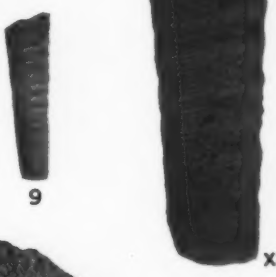
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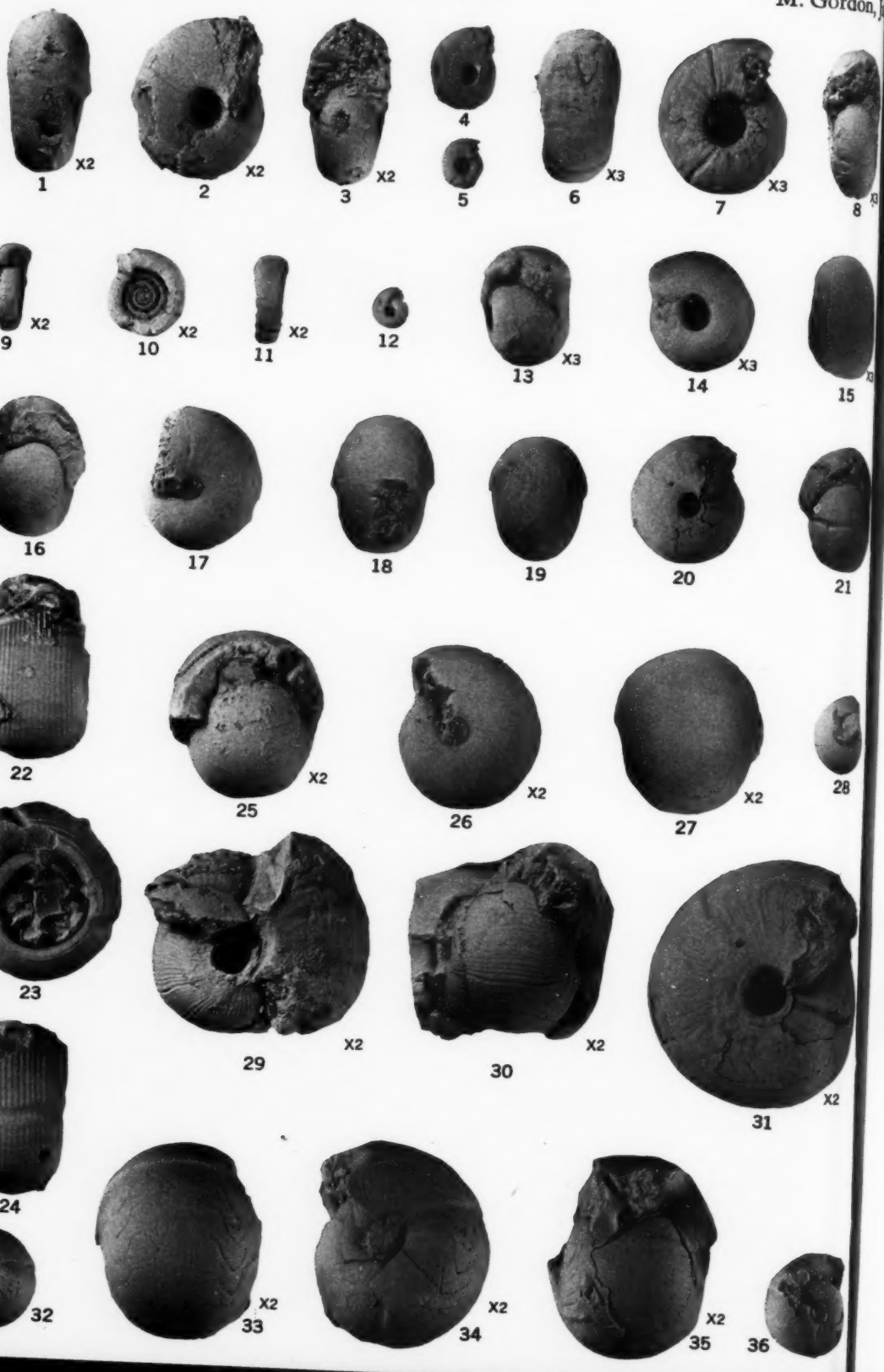
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Miller and Youngquist (1948) questionably identified specimens of this species from the Barnett formation of Texas with *Cravenoceras hesperium* Miller and Furnish. In *C. hesperium*, however, the umbilical shoulder is marked by a raised spiral cord and the umbilicus expands gradually with growth. *C. incisum* (Hyatt) as defined here is fairly common in the Barnett formation of Texas but the writer has not recognized it elsewhere.

Types.—Lectotype, no. 12034, Texas Univ. collection. Hypotype, USNM 119522.

Occurrence.—The lectotype is from the Barnett formation near Richland Springs, San Saba County, Texas. Other material studied is from the Barnett formation, upper part, USGS locality *7701*,[1] hillside east of San Saba—Chappel road, 3 miles southeast of San Saba, Texas.

Genus PARACRAVENOCERAS Gordon, n. gen.

Diagnosis.—Conch thick, discoidal to subglobose, rather narrowly umbilicate, sculptured as in *Cravenoceras* by flat transverse lamellae that are slightly raised along the orad edge. These lamellae are relatively straight across the adult shell, but are strongly sinuous in the young and immature stages, forming prominent ventrolateral salients and ventral and lateral sinuses. Umbilical shoulder generally marked by one or more raised cords. Suture with eight lanceolate pointed lobes with strongly sigmoidal sides, the ventral lobe wide and deeply cleft by the median saddle into a pair of hastate or pointed lanceolate prongs.

Type species.—*Paracravenoceras ozarkense* Gordon, n. sp., described below.

Discussion.—Shells belonging in this genus have been referred by previous authors to *Goniatites* De Haan, *Nuculoceras* Bisat, or *Cravenoceras* Bisat. The shape and sculpture of the shell resemble that of *Cravenoceras* but young individuals of typical *Cravenoceras* do not have such sinuous transverse growth lamellae. The advanced suture of *Paracravenoceras*, which resembles that of several Pennsylvanian species of *Glaphyrites*, is the principal character which distinguishes this genus from *Cravenoceras*. The suture of *Cravenoceras malhamense* (Bisat), the type species of the genus *Cravenoceras*, in contrast, has relatively short lobes, the ventral one narrow and rather shallowly divided by the median saddle. Sutures of other species of *Cravenoceras*, particularly the European ones, also have relatively narrow ventral lobes and do not have strongly lanceolate lobes. *Paracravenoceras*, therefore, appears to merit

[1] Numbers in italics are early collecting localities of the U. S. Geological Survey; the specimens are marked by numbers on green labels.

EXPLANATION OF PLATE 28

[Figures natural size unless otherwise indicated on plate]

FIGS. *1–8*—*Pygmaeoceras pygmaeum* (Mather). *1–4*, Enlarged back, side, and front views and side view of a mature topotype, USNM 119671, from USGS locality 1999, Hale formation, Prairie Grove limestone member, 3¼ miles northeast of Fayetteville, Washington County, Arkansas. *5–8*, Side view and enlarged back, side, and front views of another topotype from the same lot.

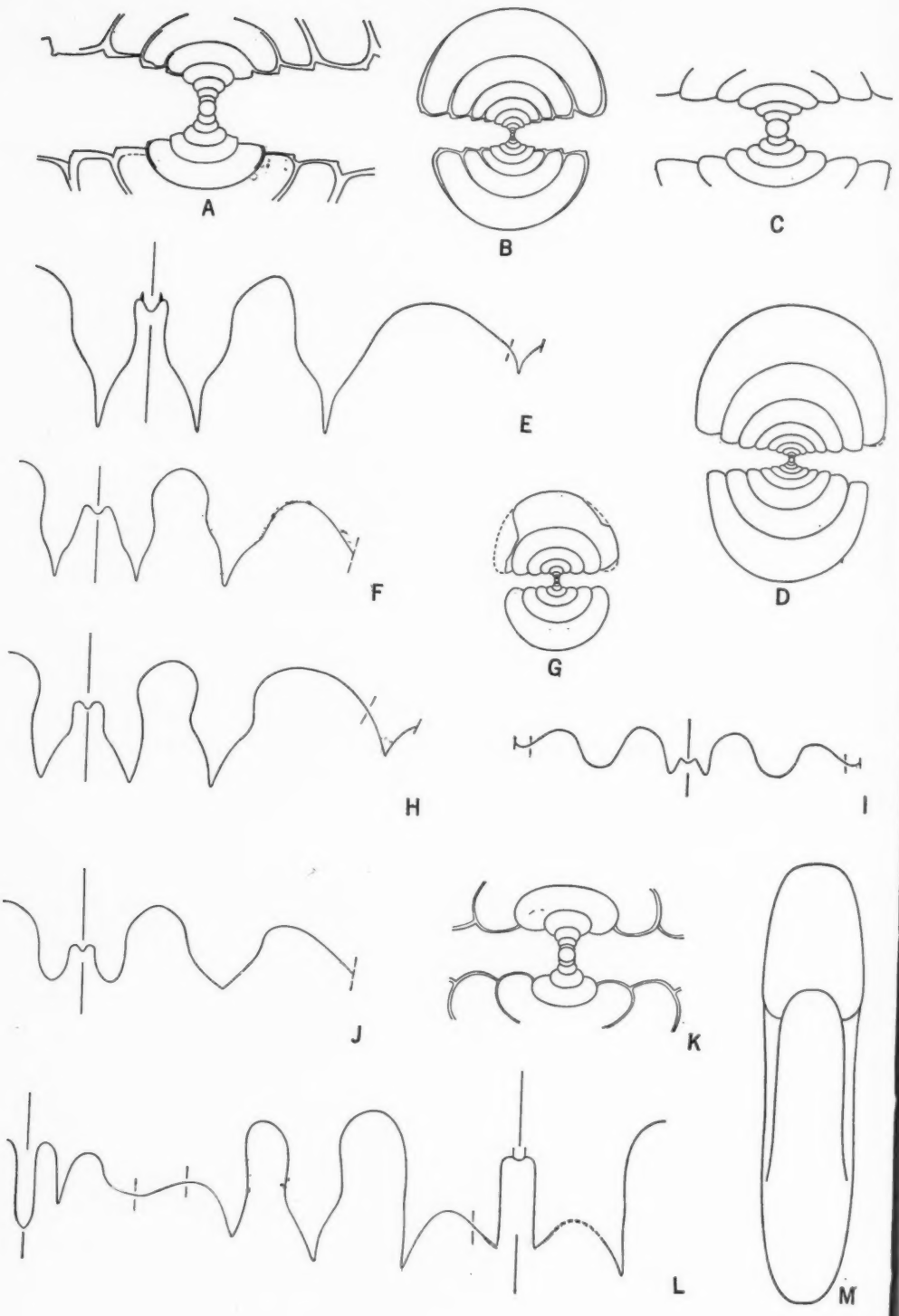
9–11—*Fayettevillea planorbis* Gordon, n. gen., n. sp. Enlarged front, side, and back views and side view of the holotype, USNM 119552, from USNM locality 3301, Fayetteville shale, lower member, 2 miles east of Fayetteville, Arkansas.

12–15,19–21,29–31—*Paracravenoceras ozarkense* Gordon, n. gen., n. sp. *12–15*, Side view and enlarged front, side, and back views of a small paratype, USNM 119542 showing the wavy transverse striae in youth, from the same locality as the last. *19–21,31*, Back, side, and front views and enlarged side view of the holotype, USNM 119539, from USGS locality 14391, Fayetteville shale, same locality as the last. *29,30*, Enlarged side and ventral views of a specimen with well preserved surface sculpture, USNM 119543, from USGS locality 17292, Fayetteville shale, lower member, near Fayetteville, Arkansas.

16–18,25–28—*Paracravenoceras barnettense* (Plummer and Scott). *16–18*, Front, side, and back views of the lectotype, P7564 Texas Bureau of Economic Geology, from Plummer locality 205-T-24. *25–28*, Enlarged front, side, and back views and side view of a paratype from the same lot.

22–24—*Neoglyphioceras hyatti* Gordon, n. nom. Front, side, and back views of the holotype, Texas University 12036.

32–36—*Cravenoceras incisum* Hyatt. Side view, enlarged back, side, and front view, and opposite side of the lectotype, Texas University 12034.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recognition as a genus closely related to but separate from *Cravenoceras*, with which it commonly is found associated. This genus is limited, so far as is now known to the United States, where it is common in, and restricted to, the Lower *Eumorphoceras* zone.

Two species are included in this genus, *Paracravenoceras barnettense* Plummer and Scott and *P. ozarkense*, n. sp. Both occur in the Barnett formation of Texas and are rare in the Caney shale of Oklahoma. *P. ozarkense* is abundant in the Fayetteville shale of Arkansas; *P. barnettense* is common in the Chainman shale in the Burbank Range, Utah.

PARACRAVENOCERAS OZARKENSE Gordon, n. sp.

Pl. 28, figs. 12–15,19–21,29–31; Text-figs. 1A,B,H,I

Goniatites sp. b GIRTY, 1909, p. 63,64.
Cravenoceras cf. *C. hesperium* Miller and Furnish. EASTON, 1942, p. 112, pl. 12, figs. 2–4; MILLER & YOUNGQUIST, 1948, p. 669,670, pl. 95, figs. 1–3.

Diagnosis.—Conch subglobose, moderately involute; venter well rounded, flanks moderately rounded; umbilical shoulder marked by one to three spiral cords. Umbilicus deep, its width equal to one-fifth shell diameter. Suture with lanceolate lobes; two prongs of broad ventral lobe diverging slightly apicad; first lateral lobe moderately narrow and hastate.

Description.—The holotype is a well-preserved phragmocone, 20 mm. in diameter. The venter, ventrolateral zones, and flanks merge in a rather even deep broad continuous curve, a little less convex near the subangular umbilical shoulders where the whorl is widest. The umbilical wall is gently convex. The umbilicus in the first three whorls is wide and shallow, but becomes rapidly narrower and deeper with growth, and generally after the fifth whorl remains constantly at a width equal to about one-fifth the shell diameter.

Surface sculpture consists of typical cravenocerid transverse lamellae. At shell diameters less than 10 mm., these are decidedly sinuous and form a narrowly rounded ventral sinus flanked by corresponding ventrolateral salients. With growth the sinuosity becomes subdued. On the outer volution of the holotype a shallow lateral sinus occurs on the outer part of each flank with a corresponding shallow orad bow, flattened across the venter; also a smaller bow on the inner flank near each umbilical shoulder. Three narrow internal varices, approximately parallel to the transverse lamellae, are present on the outer volution of the holotype. On a larger phragmocone internal varices and transverse lamellae are essentially straight across the whorl. The holotype has a single spiral cord at the umbilical shoulder. On particularly well-preserved shells, three spiral cores may be present, one at either side of the cord along the umbilical shoulder.

The external suture has a wide ventral

TEXT-FIG. *1*—Cross sections and sutures of *Paracravenoceras*, *Cravenoceras*, and *Axinolobus*.

A, B, Cross section of *Paracravenoceras ozarkense*, n. gen., n. sp., from a paratype, USNM 119544, ×5 and ×1½.
C, D, Cross section of *P. barnettense* (Plummer and Scott) from a topotype, USNM 119546, ×5 and ×1½.
E, F, External sutures of *P. barnettense* (Plummer and Scott) from a topotype, USNM 112999 (the holotype of *Goniatites choctawensis barnettensis* Miller and Youngquist) at a conch diameter of 28 mm., ×3, and from a paratype, P-7564 Univ. Texas Bur. Econ. Geology, at a conch diameter of 9.1 mm. ×6.
G, K, Cross section of *Cravenoceras incisum* (Hyatt) from a hypotype, USNM 119522, ×1½ and ×5.
H, I, External sutures of *Paracravenoceras ozarkense*, n. gen., n. sp., from a paratype, USNM 119544, at a conch diameter of 15.9 mm., ×4 and from a small paratype from the same lot at a conch diameter of 4.3 mm., ×10.
J, External suture of *Cravenoceras incisum* (Hyatt) from the lectotype, Univ. Texas 12034, at a conch diameter of 14 mm., ×4.
L, Suture of *Axinolobus modulus*, n. gen., n. sp., from the holotype, USNM 119684, at a conch diameter of 71 mm., ×2.
M, Front view in outline of the same specimen slightly reconstructed, natural size.

lobe with two pointed-lanceolate prongs that diverge slightly apicad; the lobe is divided to about three-fifths its length by an elongate subtriangular median saddle. The first lateral saddle is narrow, asymmetric and spatulate. The first lateral lobe is moderately narrow, inflated, pinched in above with a subangulation at either side and a long point. The second lateral saddle is moderately broad and asymmetrically rounded. The umbilical lobe is pointed. The internal suture consists of three pointed-lanceolate lobes that resemble the first lateral lobe but are smaller. The dorsal lobe is the longest and is separated from each lateral lobe by a narrow spatulate saddle. The second lateral internal saddle is like its external counterpart.

P. ozarkense is distinguished from *P. barnettense* principally by its more globose shape, slightly wider umbilicus, and by the less deeply divided ventral lobe and narrower, more hastate first lateral lobe of the adult suture. In shape and external ornamentation it is similar to *Cravenoceras hesperium* Miller and Furnish from which it is distinguished by the longer pointed and more lanceolate lobes of the suture, and by its sinuous transverse sculpture in the early stages.

Types.—Holotype, USNM 119539. Paratypes, USNM 119540 to 119544, inclusive.

Dimensions and proportions:

	1	2	3	4	5	6	7	8
Diameter (D) mm.	29.0	24.1	20.2	18.5	15.1	11.0	8.3	6.5
Height of last whorl (H) mm.	13.2	11.4	9.3	8.5	7.5	4.8	3.9	2.8
Width of last whorl (W) mm.	22.2	20.5	15.8	16.0	13.2	7.8	6.7	4.8
With of umbilicus (U) mm.	5.5	5.2	4.0	3.5	2.7	3.0	2.2	2.5
U/D	0.19	0.12	0.20	0.19	0.18	0.27	0.24	0.38
W/D	0.76	0.85	0.78	0.86	0.87	0.71	0.81	0.74
W/H	1.68	1.80	1.70	1.88	1.76	1.63	1.72	1.72

Specimen 3 is the holotype; the rest are paratypes; 1 is from USGS locality 15071, 2 from locality *5552*, 4 to 7 inclusive from locality 14391, and 8 from USNM locality 3301. All but *5552* are actually the same collecting locality.

Occurrence.—Fayetteville shale, lower part, USGS localities 14391, 15071, and USNM locality 3301, from pyritic shale layer, at a fork in the creek on south slope of East (Sequoyah) Mountain, about 150 yards west by south of the center of the SE¼ sec. 14, T. 16 N., R. 30 W., 2 miles east of Fayetteville, Arkansas, and USGS locality 1792, from 20 feet higher stratigraphically and a half mile upstream and north-northeast of the fork. Additional paratypes are from USGS locality *5552*, fossils from a well in the NW¼ sec. 30, T. 17 N., R. 29 W., 4 miles northeast of Fayetteville, Arkansas.

PARACRAVENOCERAS BARNETTENSE
(Plummer and Scott)
Pl. 28, figs., 16–18,25–28;
Text-figs. 1C–F

Glyphioceras incisum [part] HYATT, 1893, p. 471,472, pl. 47, figs. 46–48 [not figs. 44,45]; [part] SMITH, 1897, p. 111–121 [not pls. 13,14,15].

Goniatites crenistria Phillips [part]. SMITH, 1903, p. 68–76, pl. 10, figs. 14–16 [not pl. 10, figs. 12,13, pls. 14,15, figs. 1a–j].

Gastrioceras richardsonianum [part] GIRTY, 1909, p. 54–57 [not pl. 11, figs. 1–11].

Nuculoceras incisum (Hyatt) [part]. PLUMMER & SCOTT, 1937, p. 106–108, pl. 7, fig. 14 [not figs. 7–13].

Nuculoceras barnettense PLUMMER & SCOTT, 1937, p. 108,109, pl. 7, figs. 15–18; PLUMMER, 1950, pl. 8, figs. 15,16.

Goniatites choctawensis Shumard [part]. PLUMMER & SCOTT, 1937, p. 113,114, pl. 7, fig. 4 [not figs. 3, 5, 6]; [part]. MILLER & YOUNGQUIST, 1948, p. 658–660, pl. 96, figs. 1–3,9–12, pl. 97, figs. 8–10,19–21, pl. 98, figs. 10,11, pl. 99, figs. 3–5,8,9,13–19 [not pl. 95, figs. 16,17, pl. 97, figs. 1–7,11–18, pl. 98, figs. 1–9,12,13, pl. 99, figs. 1,2,6,7,10–12].

Goniatites choctawensis barnettensis MILLER & YOUNGQUIST, 1948, p. 659, pl. 99, figs. 16–19.

Goniatites cf. *G. cumminsi* (Hyatt). CLOUD & BARNES, 1948, pl. 44, figs. 41,42.

A restudy of Plummer and Scott's type lot shows this to be a recognizable species. Seven specimens labeled as cotypes are in the Plummer collection at the University of Texas Bureau of Economic Geology at Austin, all under the number C-106, four of them in a separate tray also carrying the number P7589. The measurements of all seven specimens are given in the table be-

low. The largest specimen, not quite 23 mm. in diameter, is hereby designated the lectotype.

A suite of topotypes in the U. S. Geological Survey collections has also been studied and has contributed measurably to our understanding of this species. Other topotypes in the U. S. National Museum collection have been examined. The shell described and figured as the holotype of *Goniatites choctawensis barnettensis* Miller and Youngquist, n. var. (1948, p. 659, Pl. 99, figs. 16–19) represents the mature phragmocone of this species and is a synonym, homonym, and topotype of *Nuculoceras barnettense* Plummer and Scott. The same specimen was figured by Cloud and Barnes (1948, Pl. 44, figs. 41,42) as *Goniatites* cf. *G. cumminsi* (Hyatt). The dimensions of this specimen are given in the table below and a drawing of the external suture is shown in Text-fig. 1E. The material studied permits the following revised description of this species.

Description.—Conch narrowly subglobose to thick discoidal, becoming gradually more compressed with growth; venter well rounded, flanks somewhat flattened; umbilical shoulder subangular and marked on well-preserved specimens by a spiral cord. The cross section of the whorl is crescentic, increasing in curvature with growth (Text-fig. 1C,D). The umbilical wall is convex, the umbilicus narrows deep, generally slightly less than one-sixth the conch diameter and retaining approximately the same proportionate width during growth (i.e., expanding gradually).

Surface sculpture consists principally of narrow flat transverse lamellae, the arterior end of each raised very slightly as in *Cravenoceras*. In the young shell these are decidedly sinuous and form moderately deep rounded ventral and lateral sinuses separated by corresponding ventrolateral salients. These decrease in sinuosity with growth until in the mature phragmocone the transverse sculpture is nearly straight across the flanks and forms a very shallow, broad ventral sinus. Internal varices following approximately the same course as the transverse lamellae are not common in this species and where present are shallow and occur spaced approximately one quarter volution apart.

The suture of a young paratype (Text-fig. 1F) is not unlike that of *Paracravenoceras ozarkense*, n. sp., except that the first lateral lobe is not as pinched in above. The suture of the adult phragmocone has a broad ventral lobe divided to more than four-fifths of its length by a flask-shaped median saddle; the prongs are inflated in the orad half and terminate apicad in long slender points. The first lateral saddle is decidedly asymmetric, moderately narrow and narrowly rounded orad. The first lateral lobe, likewise is asymmetric, about one-half the width of the ventral lobe, and terminates apicad in a long point, the sides diverging orad. The second lateral saddle rounds asymmetrically to the umbilical shoulder. The umbilical lobe is short and pointed.

Discussion.—One of Hyatt's types of *Glyphioceras incisum* belongs in *P. barnettense* but Hyatt's other type of *G. incisum* belongs in a different species and this specimen has been designated the lectotype of *Cravenoceras incisum* (Hyatt), thus eliminating the possibility of synonymy of *Nuculoceras barnettense* Plummer and Scott with *Glyphioceras incisum* Hyatt.

P. barnettense can be distinguished relatively easily from *Cravenoceras incisum* (Hyatt) with which it is associated in the Barnett formation: in young stages by its strongly sinuous transverse lamellae in contrast to the nearly rectilinear ones of *C. incisum;* in later stages by its suture with sharply pointed lobes, the ventral lobe 1½ to 2 times the width of the first lateral lobe, in contrast to the blunter lobes of *C. incisum* with ventral and first lateral lobes of subequal width. Its differences from *P. ozarkense*, n. sp. are discussed under that species.

A single specimen of *P. barnettense* from USGS locality *3948*, Caney shale, Antlers quadrangle. Oklahoma, was included by Girty (1909, p. 57) in the material he referred to *Gastrioceras richardsonianum* Girty in his original description of that species. It was not, however, one of the primary types of *G. richardsonianum.*

One of the specimens figured by Plummer and Scott (1937, Pl. 7, fig. 14) as *Nuculoceras incisum* (Hyatt) has a typical *Para-*

cravenoceras suture and also belongs in *Paracravenoceras barnettense.*

Dimensions and proportions:

	1	2	3	4	5	6	7	8	9
Diameter (D) mm.	42.3	29.5	22.6	16.4	12.4	10.7	10.6	9.0	6.0
Height of last whorl (H) mm.	22.5	14.3	11.9	8.1	6.7	5.4	5.0	3.5	2.6
Width of last whorl (W) mm.	26.0	21.3	16.5	14.5	11.6	9.5	—	7.6*	6.1
Diameter of umbilicus (U) mm.	6.8	4.7	3.0	2.3?	1.9	1.9	1.8	—	1.0
U/D	0.16	0.15	0.13	0.14	0.15	0.18	0.17	—	0.17
W/D	0.61	0.72	0.73	0.88	0.93	0.89	—	0.84	1.00
W/H	1.15	1.49	1.39	1.70	1.73	1.76	—	2.18	2.35

* Twice the half width.

Specimen 1 is a topotype, the holotype of *Goniatites choctawensis barnettensis* Miller and Youngquist; 2 is a topotype from USGS locality *7701* figured in Text-fig. 1; 3 is the lectotype and 4 to 9, inclusive are paratypes. All are actually from the same collecting locality.

Texas specimens of this species were included by Miller and Youngquist (1948) in *Goniatites choctawensis* Shumard, which they gave a broad interpretation. They also included in *G. choctawensis* species which the writer would identify as *Goniatites cumminsi* (Hyatt) and *G. granosus* Portlock. According to the writer's interpretation, typical *G. choctawensis* is confined to an earlier stratigraphic zone which is not represented in the Barnett formation of Texas, but occurs at the base of the Caney shale locally in Oklahoma.

Specimens identified as *Paracravenoceras barnettense* from the Chainman shale of Utah agree closely in shape with Texas specimens of this species, but the first lateral lobes of their sutures are somewhat intermediate between those of *P. barnettense* and *P. ozarkense.*

Types.—Lectotype and paratypes, three specimens in lot P-7564 of which the largest, figured by Plummer and Scott (1937, Pl. 7, figs. 16,18) is designated the lectotype; additional specimens in lot P-7589, collection of Univ. Texas, Bureau Econ. Geology. Hypotypes USNM 112999, 119546.

Occurrence.—Barnett formation, Plummer locality 205-T-24, USGS locality *7701*, hillside exposure at abandoned lime kiln on San Saba-Chappel road, 3 miles southeast of San Saba, Texas.

Genus FAYETTEVILLEA Gordon, n. gen.

Diagnosis.—Conch planorbiform; whorl depressed, reniform in cross section; umbilicus large; umbilical shoulder rounded on some specimens marked by weak irregularly-spaced nodelike swellings. Surface sculptured by transverse growth striae and constrictions that are protractive across flanks and form faint sinus in middle of venter. Suture goniatitid; ventral lobe narrow with convex sides divided by short subtriangular median saddle; first lateral saddle rounded spatulate; first lateral lobe rounded, shorter than the ventral lobe; second lateral saddle rounded; umbilical lobe shorter than first lateral lobe, rounded.

Type species.—*Fayettevillea planorbis* Gordon, n. sp., described below.

Discussion.—*Fayettevillea* is distinguished from young stages of the genus *Pronorites* with which it may occur and from young prolecanitids by its tighter coiling, the presence of growth constrictions, and its goniatitid suture. The planorbid coiling of *Fayettevillea* is similar to certain species of *Kazakhstania* Librovitch and *Nomismoceras* Frech, but in *Kazakhstania* the ventral lobe is undivided, and in *Nomismoceras* the sides of the shallowly notched ventral lobe diverge widely orad.

The rather narrow ventral lobe and rounded first lateral lobe of *Fayettevillea* suggest a relationship with the highly ribbed genus *Entogonites* Kittl, particularly the species *E. borealis* Gordon (1957, p. 53) from the Upper Mississippian of northern Alaska. In the Alaskan species, however, the sides of the ventral lobe are straight and nearly parallel.

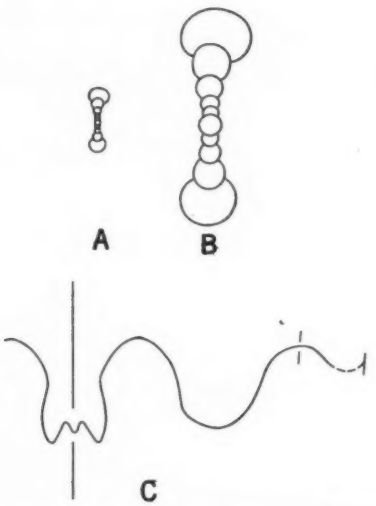
Distribution.—This genus occurs in Arkansas in the Fayetteville shale near Fayetteville, Washington County, and at Marshall, Searcy County. A specimen (USNM 119586) from the Caney shale about 15 miles south-southeast of McAlester, Oklahoma (USGS loc. *2079*) illustrated by Girty (1909, Pl. 11, fig. 10) as one

of the primary types of *Gastrioceras richardsonianum* Girty probably belongs in *Fayettevillea*.

FAYETTEVILLEA PLANORBIS
Gordon, n. sp.
Pl. 28, figs. 9–11;
Text-fig. 2

Diagnosis.—Same characters as for the genus.

Description.—The holotype is a small phragmocone showing the protoconch and approximately five-volutions, the outermost of which preserves several sutures. The



TEXT-FIG. 2—*Fayettevillea planorbis*, n. gen., n. sp. A, B, Cross section of a paratype (USNM 119555), ×1½ and ×5. C, External suture of the holotype (USNM 119552) at a conch diameter of 6.7 mm.

shell is decidedly evolute, the width of the umbilicus equal to about three-fifths of the diameter of the conch. In the holotype several faint nodelike swellings are present along the umbilical shoulder but are widely and irregularly spaced, are absent on most of the paratypes, and merely suggested on others. Constrictions of growth are spaced one to three on the outer whorls, but are absent on the early whorls and in three of the paratypes.

The body whorl and internal suture are not known.

	Holotype	Paratype
Diameter (D)	7.3 mm.	4.7 mm.
Height of last whorl (H)	2.0 mm.	1.0 mm.
Width of last whorl (W)	2.8 mm.	1.6 mm.
Width of umbilicus (U)	4.3 mm.	2.9 mm.
U/D	0.59	0.62
W/D	0.38	0.34
W/H	1.40	1.60

Types.—Holotype, USNM 119552. Paratypes, USNM 119553–119555, inclusive.

Occurrence.—Fayetteville shale, lower member, USNM locality 3301 (Holotype and paratype), pyritic shale layer at fork in creek on south slope of East (Sequoyah) Mountain, about 150 yards west by south of the center of the SE¼ sec. 14, T. 16 N., R. 30 W., 2 miles east of Fayetteville, Arkansas; USGS localities 14363 (2 paratypes) and 15069 (3 paratypes), fossils weathering from a 15-foot interval 22 to 37 feet above the base of the Fayetteville shale, east side of U. S. Highway 65, near center of sec. 31, T. 15 N., R. 15 W., just outside city limits of Marshall, Arkansas.

Genus PYGMAEOCERAS Gordon, n. gen.
Gastrioceras of authors [part].

Diagnosis.—Conch rather small, thick-discoidal, moderately evolute in adolescence, becoming moderately involute at maturity; venter well-rounded; flanks compressed. Surface sculpture in immature and barely mature shells of fine umbilical plications, pilae, or nodelike riblets from which issue fine gently sinuous transverse lirae. Lirae and internal varices form broad shallow ventral and lateral sinuses and corresponding ventrolateral salients, the ventral sinus generally deeper than the rest. Umbilical riblets and transverse lirae become obsolete and generally die out by late maturity. Suture simple, consisting of eight lobes and a corresponding number of saddles. First lateral lobe and prongs of ventral lobe rounded to bluntly pointed.

Type species.—*Gastrioceras pygmaeum* Mather, 1915.

Discussion.—The relatively involute compressed conch, obsolescent umbilical riblets, and simple suture commonly with rounded lobes distinguish this genus from *Gastrioceras* Hyatt, under which most of the species now placed in *Pygmaeoceras* were originally described.

The type species of the genus was referred to *Cravenoceras* Bisat by Plummer and Scott (1937, p. 265) and to "*Gastrioceras*" by Miller and Moore (1938, p. 347). This species should not be confused with *Goniatites pygmaeus* Winchell, 1865 which Miller and Garner (1955, p. 142) have referred to *Münsteroceras*?.

Besides the type species, *Gastrioceras venatum* Girty and *Gastrioceras*? *sigma* Wright are included in this genus. An additional species from rocks of late Morrow age is being described in the writer's Arkansas cephalopod report.

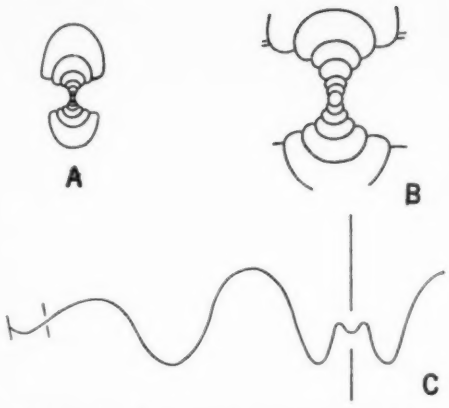
Distribution.—In the United States *Pygmaeoceras* is known in the Lower Pennsylvanian (Morrow series) of Arkansas and northeastern Oklahoma and in the Middle Pennsylvanian (Des Moines series) of central Oklahoma. In northwest Europe the species we have referred to *Pygmaeoceras* occurs in Upper Namurian rocks in the Lower *Gastrioceras* (G_1) zone in Great Britain and in the *Reticuloceras superbilingue* zone in Germany.

PYGMAEOCERAS PYGMAEUM (Mather)
Pl. 28, figs. 1–8; Text-fig. 3

Gastrioceras pygmaeum MATHER, 1915, p. 243, 244, pl. 16, figs. 11–11b.
Cravenoceras pygmaeum PLUMMER & SCOTT, 1937, p. 265.
"*Gastrioceras*" *pygmaeum* MILLER & MOORE, 1938, p. 347,348, Pl. 44, figs. 3,4.

Diagnosis.—Conch small, narrowly thick-discoidal; whorl slightly wider than high, with fine transverse lirae and growth constrictions forming both lateral and ventral sinuses. Ventral lobe of suture wider than first lateral saddle.

Description.—The largest topotype in the U. S. Geological Survey collection is nearly 13 mm. in diameter, or about 2½ times the size of the lectotype. The whorl has a well-rounded venter and rather flat flanks that converge slightly ventrad. The umbilical shoulder is subangular and the umbilical wall well-rounded. The width of the umbilicus ranges from about three-tenths to a little over one-third the diameter of the shell. Cross sections (Text-fig. 3) show that the first three and one-half whorls are planorbitally coiled.



TEXT-FIG. 3—*Pygmaeoceras pygmaeum* (Mather). A, B, Cross section of a topotype (USNM 119671), ×1½ and ×5. C, External suture of another topotype, at a conch diameter of 12.9 mm., ×5.

An indefinite number, but approximating 30 per volution, of narrow transverse node-like riblets are slightly protractive across the umbilical shoulder from the middle of the umbilical wall to just within the flank. Each of these gives rise to three or four fine transverse lirae and an additional four lirae generally occur between riblets. The lirae are sinuous and over the venter have considerably wider interspaces. Growth constrictions roughly parallel the lirae, generally spaced one-third to one-quarter of a volution apart and with some occurring sporadically between these. The ventral sinus outlined by lirae and constrictions is broadly rounded and not much more than 1 mm. deep on the largest topotype. The lateral sinuses are even shallower but are clearly discernible; rounded ventrolateral salients occur between the ventral and lateral sinuses. The nodes and lirae become obsolete with growth of the conch and disappear on some shells.

The outermost suture seen on the largest specimen has a rather broad ventral lobe indented to about one-half its length by a narrow trapezoidal median saddle; the prongs are pointed in a tiny gothic arch. The first lateral saddle is not as wide as the ventral lobe and is broadly rounded orad. The first lateral lobe is V-shaped with convex sides and pointed. The second lateral

saddle rounds asymmetrically to the short, broad bluntly-pointed umbilical lobe. The internal suture was illustrated by Mather (1915, Pl. 16, fig. 11b) and consists of a narrow dorsal and pair of first lateral lobes, separated by narrow rounded first lateral saddles and flanked by broader asymmetrically rounded second lateral saddles.

Dimensions and proportions:

	A	*B*	*C*	*Lectotype*
Diameter (D) mm.	12.7	11.1	8.3	5.2
Height of last whorl (H) mm.	6.3	5.2	3.4	2.4
Width of last whorl (W) mm.	7.1	5.7	4.6	2.6
Width of umbilicus (U) mm.	3.7	3.3	3.0	1.6
U/D	0.29	0.30	0.36	0.31
W/D	0.56	0.51	0.55	0.50
W/H	1.13	1.10	1.35	1.10

Discussion.—This species was described originally from a dozen or so syntypes collected in a quarry about 3½ miles northeast of Fayetteville, Arkansas. The syntype figured by Mather (1915) on plate 16, figures 11–11b is here designated the lectotype. This specimen was also figured by Miller and Moore (1938, Pl. 44, figs. 3,4). The syntypes are numbered 16121 in the University of Chicago's Walker Museum collection. At the time of the present study Mather's cephalopod types had been misplaced and were not available. The description above was based largely on topotypes from the same quarry.

Types.—Lectotype and paratypes, no. 16121, Walker Museum collection, University of Chicago. Hypotypes, USNM 119671.

Occurrence.—Hale formation, Prairie Grove member, USGS locality 1999, abandoned quarry near center SE¼ sec. 2, T. 16 N., R. 30 W., 3½ miles northeast of Fayetteville, Arkansas. Same as Mather's locality 135.

Genus AXINOLOBUS Gordon, n. gen.

Diagnosis.—Discoidal, moderately evolute shells with compressed whorls; narrow venter, broad flanks, and narrow umbilical slopes all gently convex; ventrolateral and umbilical shoulders strongly rounded. Umbilicus shallow, broadly stepped within, equal to approximately one-third the diameter of the conch in the type species. Test moderately thin, ornamented by raised transverse threads forming rounded lateral sinus on flanks adjacent to umbilicus, as in *Winslowoceras*. Suture with ten lobes, the ventral one broad with straight subparallel sides, terminating apicad in sharp points at outer edges, deeply indented by median saddle roughly in shape of inverted goblet (without base). Other lobes and saddles approximately as in *Winslowoceras*.

Type species.—*Axinolobus modulus* Gordon, n. sp., described below.

Axinolobus differs from *Winslowoceras* Miller and Downs, as well as from *Eowellerites* Ruzhecev in its slightly convex venter and the peculiar axe-shaped ventral lobe of the suture. The type specimen of *A. modulus* Gordon, n. sp., from the Morrow of northeast Oklahoma, is the only example known of *Axinolobus*.

AXINOLOBUS MODULUS
Gordon, n. sp.
Text-figs. 1–L,M

Diagnosis.—Same as for the genus.

Description.—The holotype is an internal mold of a broken phragmocone that attained a diameter of at least 75 mm. The conch is discoidal, moderately evolute, the outer volution covering about two-fifths of the preceding one. The venter is narrow and very gently convex as are the flanks and umbilical slopes; the ventrolateral and umbilical shoulders are strongly rounded. The greatest width is about one-third of the distance from the umbilical shoulder to the venter. A large patch of the test adhering to one flank of the penultimate volution is sculptured by raised transverse threads that form a broad rounded lateral sinus adjacent to the umbilicus.

The suture is composed of ten lobes, the

ventral one broad with straight subparallel sides terminating apicad in sharp points at the outer edges, deeply indented by the median saddle which is roughly in the shape of an inverted goblet (without base). The first and second lateral lobes are lanceolate and acuminate; the first and second lateral saddles are spatulate, narrowly rounded at the orad end; the third lateral saddle is short, broad, asymmetric, and crosses the umbilical shoulder and slope almost to the umbilical seam. The lobes and saddles are progressively shorter dorsad. The internal suture has a very shallow broad lobe centering at or immediately adjacent to each umbilical seam, a narrow acuminate V-shaped lateral lobe at either side of a longer bluntly pointed dorsal lobe with subparallel sides; all the lobes of the internal suture are separated by narrow rounded saddles.

Dimensions and proportions of the holotype are taken at the most complete section, one-third of a volution from the oral end of the specimen, and are as follows: diameter (D), 70.5 mm.; height of whorl (H), 24.6 mm.; width of whorl (W), 16.0 mm.; width of umbilicus (U), 26.0 mm. (slightly exaggerated by distortion). These give the following shell ratios: $U/D = 0.35$, $W/D = 0.23$, and $W/H = 0.65$.

Discussion.—This species is distinguished from all similar compressed ammonoids by the unique ventral lobe of its suture, which is somewhat reminiscent of certain archaic types of axelike weapons, hence the generic name.

Holotype.—USNM 119684.

Occurrence.—Morrow series, upper part, USGS locality 2000; hillside east of the railroad in the SE¼ sec. 35, T. 13 N., R. 20 E., 3 miles northwest of Gore, Muskogee County, Oklahoma (same as Mather's loc. 304).

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LOWER CRETACEOUS (ALBIAN) FOSSILS FROM SOUTHWESTERN OREGON AND THEIR PALEOGEOGRAPHIC SIGNIFICANCE[1]

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ABSTRACT—Lower Cretaceous marine strata exposed near Mitchell, central Oregon, were previously the only known deposits of Albian age in Oregon. Recognition of another exposure of Albian strata on Grave Creek, southwestern Oregon, permits speculation on the paleogeography of Oregon during Albian time. It is suggested that the Albian sea in central Oregon had a connection with the open ocean to the west and transgressed southerly and southeasterly. The Grave Creek fauna consists, in part, of: *Oxytropidoceras?* sp. indet., *Lyelliceras* n. sp.?, *Cleoniceras? dilleri* Jones, n. sp., *Inoceramus* (*Actinoceramus*) *concentricus* Parkinson, *I.* (*A.*) *"subsulcatus"* Wiltshire, *I.* (*A.*) *salomoni* d'Orbigny, and *Megatrigonia* (*Apiotrigonia*) *condoni* (Packard).

INTRODUCTION

UNTIL now the Lower Cretaceous marine strata exposed near Mitchell, central Oregon, were the only beds in Oregon known to contain fossils of Albian age. Because this single, isolated occurrence is separated by almost 300 miles from other Albian rocks, reconstruction of the late Early Cretaceous paleogeography of Oregon has been difficult. Cretaceous rocks outcropping on Grave Creek, southwestern Oregon, are herein interpreted, in part, as Albian in age; hence, this locality extends our knowledge of the Albian rocks and faunas of the West Coast of North America and permits speculation on the paleogeography of Oregon during late Early Cretaceous time.

The illustrated specimens are deposited in the United States National Museum, Washington, D. C.

Dr. Ralph W. Imlay, U. S. Geological Survey, kindly gave advice on the identification of the ammonites.

ROCKS OF ALBIAN AGE IN OREGON

Mitchell, Oregon Area.—Rocks of Albian age exposed near the town of Mitchell in central Oregon comprise 4,000 or 5,000 feet of marine shale including beds of sandstone and conglomerate. A detailed description of the beds near Mitchell is not available, but studies of the stratigraphy and fauna are in progress by Professor D. Wilkinson of Oregon State College, and Dr. Earl L. Packard of Stanford University.

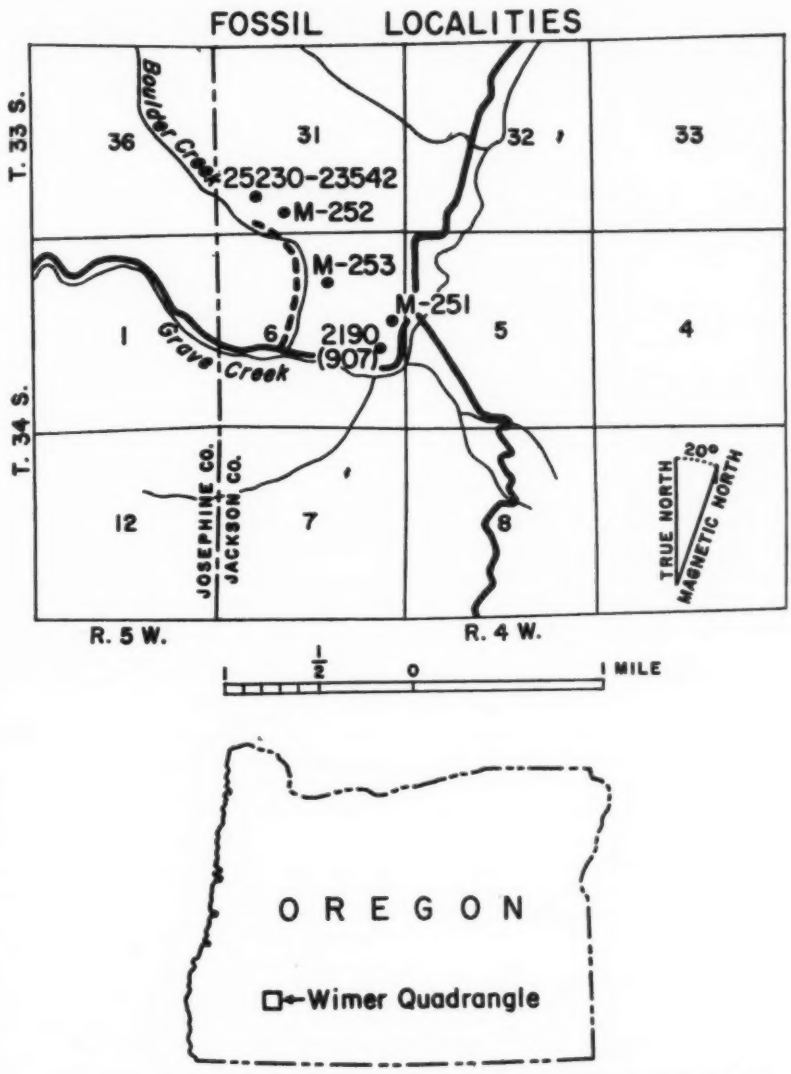
Merriam (1901, p. 449) briefly described the section at Mitchell and correlated the rocks with the Knoxville formation of California. Later, Packard (1929, p. 166) suggested that the lower part of the shale is of Horsetown age, but presented no supporting fossil evidence. The Albian age of this deposit was established by Packard (1956, p. 298–402) on the basis of an *Engonoceras* found in the Mitchell quadrangle.

The fossil succession at Mitchell is still imperfectly known. Briefly, the lower part of the section is characterized by the ammonites *Leconteites*, *Puzosigella*, *Brewericeras*, and *Douvilleiceras* of probable late early Albian age. The upper beds contain several species of *Mortoniceras* and *Desmoceras* (*Pseudouhligella*) of late Albian age. A diagnostic middle Albian ammonite fauna is not yet known at Mitchell, but beds of this age are probably present.

Upper Cretaceous species have not been found at Mitchell, although Cenomanian beds containing *Turrilites* and *Desmoceras* (*Pseudouhligella*) are present nearby on Battle Creek, at Antone, and in the Suplee area.

Grave Creek, Oregon, Area.—The sedimentary rocks exposed on Grave Creek (Text-fig. 1) comprise several hundred feet of greenish-brown, fine- to medium-grained sandstone with occasional conglomeratic layers, overlain by an unknown thickness of

[1] Publication authorized by the director, U. S. Geological Survey.



TEXT-FIG. 1—Fossil localities on Grave Creek in the western part of the Wimer Quadrangle, southwestern Oregon.

poorly exposed siltstone. These rocks were first described by Diller (1893, p. 216) who correlated them with the upper part of the Shasta group (Lower Cretaceous) of California. No fossil evidence was given in support of this age assignment. Later Diller and Kay (1924, p. 3–4) mapped the Grave Creek area and correlated the Cretaceous rocks with the Upper Cretaceous "Chico" formation of California. Again, no fossil evidence was cited other than to state that ". . . *Trigonia* and other characteristic forms are abundant."

A Late Cretaceous age for the Grave Creek strata was supported by Peck, Imlay, and Popenoe (1956, p. 1980) who assigned a Turonian age based on the ammonites *Collignoniceras* and *Tragodesmoceras*. A reexamination of their material by the author indicates that these ammonites should be

referred to *Lyelliceras* and *Cleoniceras*? respectively. These identifications have been confirmed by R. W. Imlay. Anderson (1958, p. 22) also considered the rocks in the Grave Creek area to be Turonian, but gave no supporting evidence.

Jacksonville, Oregon, Area.—Albian rocks have been reported by Anderson (1958, p. 18) in the Jacksonville area of southwestern Oregon. Anderson lists the following species, among others, from Dark Hollow, five miles east of Jacksonville: *Beudanticeras* aff. *B. haydeni* (Gabb), *Pervinqueria* sp., *Brancoceras parvum* (Anderson), and *Mantelliceras oregonense* Anderson. Detailed collecting in Dark Hollow by geologists of the U. S. Geological Survey and of the Humble Oil and Refining Company has failed to substantiate Anderson's faunal list, and no definite Albian species have been found. In brief, the Dark Hollow section consists of a lower graywacke sandstone containing the Cenomanian ammonites *Desmoceras* (*Pseudouhligella*) and *Calycoceras*, in fault contact with dark gray siltstone containing lower Turonian *Inoceramus labiatus* (Schlotheim), *Mesopuzosia*, and *Kanabiceras*.

The Albian genus *Brancoceras* is also reported by Anderson (1958, p. 259) from the "49" placer mine, about two miles east of Dark Hollow. Again, extensive collecting from this locality has failed to produce fossils older than Turonian, so the reported occurrence of Albian sedimentary rocks in the Jacksonville area remains unsubstantiated.

AGE AND CORRELATION OF THE GRAVE CREEK STRATA

All of Grave Creek fossils herein discussed were collected from sandstones in the lower part of the section. An acanthoceratid ammonite was found in the overlying siltstone in 1901 by G. H. Pease of Placer, Oregon, in a locality about 2 miles upstream (northeast) from the Albian localities. This ammonite indicates a probable Cenomanian age for the upper part of the Grave Creek strata.

The complete fauna from Grave Creek is as yet undescribed and only those species indicative of Albian age are discussed in this report. These species are:

Oxytropidoceras? sp. indet.
Lyelliceras n. sp.?
Cleoniceras? *dilleri* Jones, n. sp.
Inoceramus (*Actinoceramus*) *concentricus* Parkinson
Inoceramus (*Actinoceramus*) "*subsulcatus*" Wiltshire
Inoceramus (*Actinoceramus*) *salomoni* d'Orbigny

The genus *Oxytropidoceras* ranges from upper lower Albian through middle Albian, with its most prolific development in the middle Albian. *Oxytropidoceras* is common in the Albian beds of northern California, where, according to Murphy (1956, p. 2114–2115,2119), the zone of *O. packardi* overlies the upper lower Albian zone of *Brewericeras* [="*Beudanticeras*"] *hulenense*. *Oxytropidoceras* is also characteristic of the middle Albian of Peru (Benavides, 1956, p. 395) and Texas (Adkins, 1928, p. 225).

The genus *Lyelliceras* has not been known previously from the Albian of California or Oregon. Anderson (1958, p. 24, pl. 8, figs. 5,5a) reported the occurrence *Lyelliceras stanislausense* Anderson from Garzas Creek in central California. This species, however, does not belong to *Lyelliceras* but to the lower Turonian genus *Kanabiceras*. The genus *Lyelliceras* ranges from lower Albian through middle Albian, but is most common in the lower part of the middle Albian. Benavides (1956, p. 395) records several species of *Lyelliceias* from the middle Albian zone of *Oxytropidoceras carbonarium* in northern Peru.

Cleoniceras is restricted to the lower Albian and basal part of the middle Albian (Wright, 1957, p. 394) and is most commonly found in the upper part of the lower Albian, in the zone of *Douvilleiceras monile*, according to Breistroffer (1947, p. 40).

Inoceramus (*Actinoceramus*) *concentricus* Parkinson and *I.* (*A.*) "*subsulcatus*" Wiltshire are both well known Albian species with nearly world-wide distribution. *I.* (*A.*) *concentricus* ranges throughout the middle and upper Albian, but *I.* (*A.*) "*subsulcatus*" is confined to upper Albian rocks in England (Woods, 1911, p. 267,269). In Texas, however, Boese (1927, p. 189–193) records *I. subsulcatiformis* Boese, which probably is identical to *I.* (*A.*) *subsulcatus*, from the middle Albian Edwards limestone. *I.* (*A.*)

salomoni occurs only in lower Albian deposits in England (Woods, 1911, p. 264), but Benavides (1956, p. 395) records it from the middle Albian of Peru.

Megatrigonia (*Apiotrigonia*) *condoni* (Parkard) has been found by the writer at Texas Springs in northern California where it is associated with *Brewericeras hulenense* (Anderson) in beds of late early Albian age.

The association of these species indicates a probable late early to middle Albian age for the lower part of the Grave Creek strata. A more precise date is not warranted by the data in hand. These beds are probably in part correlative with the upper portion of the Ono formation of Murphy (1956) of northern California and with the lower or middle part of the shale sequence exposed at Mitchell, central Oregon.

ALBIAN PALEOGEOGRAPHY IN OREGON

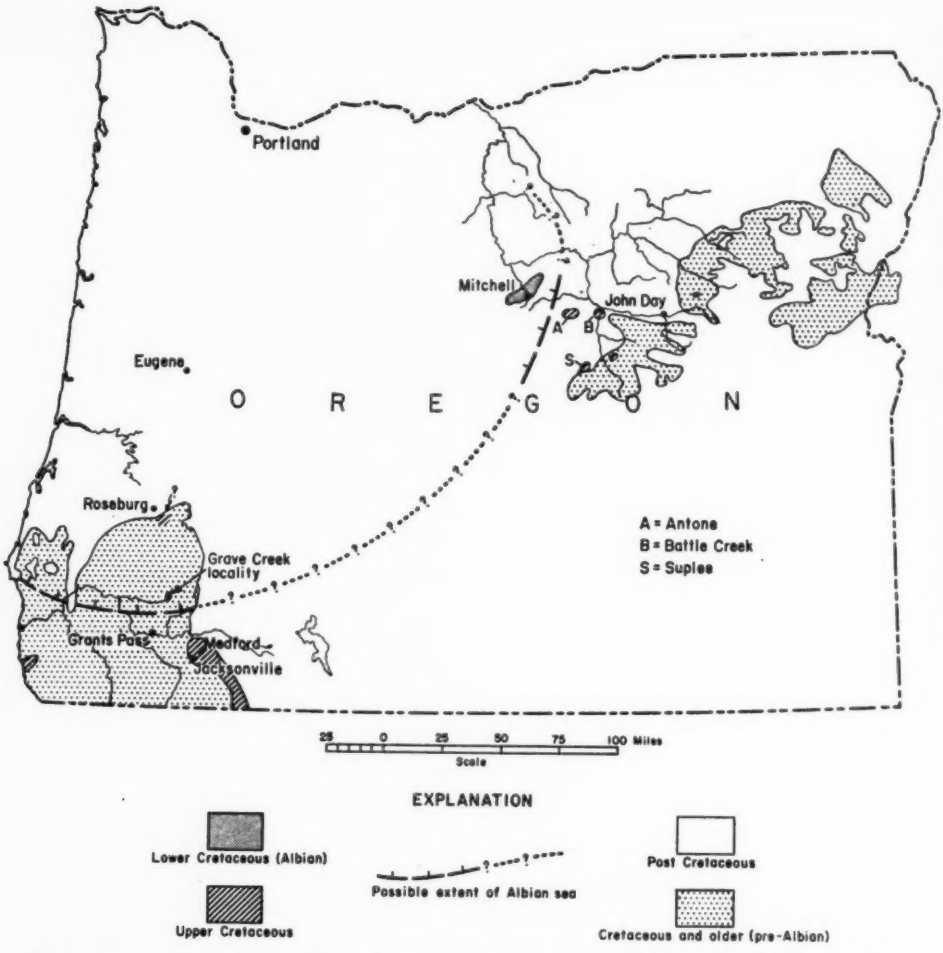
The Albian seaway well may have covered much of western and central Oregon (Text-fig. 2). Its northern limit is unknown, but presumably did not extend as far north as the Puget Sound area, Washington, as only rocks of very early Early Cretaceous and late Late Cretaceous age are exposed on the San Juan Islands and Vancouver Island (McLellan, 1927, p. 114; Usher, 1952, p. 7). Albian beds outcrop to the north on the Queen Charlotte Islands and in southern Alaska, but this northern seaway had no known connection to the south.

The Grave Creek locality marks the approximate southern extent of the Albian seaway in Oregon as Cenomanian beds rest directly on Triassic(?) rocks to the south in the Jacksonville area. No evidence is known for a connection of the Albian sea of Oregon and the Albian sea of the Sacramento Valley, California. The eastern limit of the seaway may have been between Mitchell and Antone in central Oregon, where Cenomanian beds outcrop. The Albian sea possibly had a connection with the open ocean to the west or northwest and transgressed on the land in a southerly and southeasterly direction.

FOSSIL LOCALITIES

Wimer 15′ Quadrangle

U.S.G.S. Mesozoic Locality Number	Description	Collector and Date
907	Grave Creek, Jackson County, Ore., probably same as 2190.	W. Q. Brown, date unknown
2190	Grave Creek, Jackson County, Ore., 50′ to 100′ above base; NE¼SE¼, sec. 6, T. 34 S., R. 4 W.	T. W. Stanton, 1900
23542	Boulder Creek, Jackson County, Ore., tributary to Grave Creek; conglomerate streaks in sandstone at altitude of 2,700′ or 200′ above creek; SW¼ sec. 31, T. 33 S., R. 4 W.	F. G. Wells, 1951
25230	Boulder Creek, Jackson County, Ore., tributary to Grave Creek, about ½ mile above junction; SW¼, sec. 31, T. 33 S., R. 4 W.	Hollis Dole, Dallas Peck, and R. W. Imlay, 1954
M-251	Grave Creek, Jackson County, Ore.; just west of center of section line between secs. 5 and 6, T. 34 S., R. 4 W. On west side of road. Upper (?) part of sandstone unit.	David L. Jones 1958, and Jones and W. P. Popenoe, 1958
M-252	Boulder Creek, Jackson County, Ore., tributary to Grave Creek; about ½ mile above junction; gully on north side of creek at elevation of 2,600′–2,700′; SW¼, sec. 31, T. 33 S., R. 4 W.	David L. Jones, 1958
M-253	Boulder Creek, Jackson County, Ore., tributary to Grave Creek; about ¼ mile above junction and 300′ above creek bed; SW¼NE¼, sec. 6, T. 34 S., R. 4 W.	David L. Jones, 1958



TEXT-FIG. 2—Location of Albian outcrops and possible extent of the Albian sea in Oregon.

SYSTEMATIC PALEONTOLOGY

Class CEPHALOPODA

Genus LYELLICERAS Spath, 1921

Type species—*Ammonites lyelli* (Leymerie MS.) d'Orbigny, 1841

LYELLICERAS n. sp. ?

Pl. 29, figs. 11,15,16

Description.—Shell discoidal, compressed; umbilicus fairly wide; whorl section subquadrate; umbilical wall nearly vertical, umbilical shoulder broadly rounded. Intercostal area slightly convex, costal area flat; sides subparallel. Ventrolateral shoulder rounded; venter gently arched. Eleven ribs present on preserved half-whorl; ribs prorsiradiate on inner one-third and radiate on outer two-thirds, becoming very weak or absent on venter. Three rows of lateral tubercles and one row of ventral tubercles present on ribs; the lowest row, located just above umbilical shoulder, first appears at a diameter of 30 mm.; a second row of pointed tubercles appears earlier than the lower row and is located at the end of the second third of the ribs; a third row of spirally elongate tubercles is located on the ventrolateral margin. The tubercles of last row, located on the mid-venter, are poorly preserved but appear to correspond in size and number to the ribs. Suture unknown.

Measurements.—(in mm.)

Specimen	Diameter	Height	Breadth	(B/H)	Diam. of Umbilicus	Umbilicus/ Diameter %
U.S.N.M. No. 130184	30	11	9 (costal) 6 (intercostal)	0.81 0.54	6+	20.0+

Remarks.—The Grave Creek specimen seems to be closely related in whorl section and ornamentation to *Lyelliceras pseudolyelli* (Parona and Bonarelli, 1897, p. 99, pl. 14, fig. 2). It differs from *L. pseudolyelli* mainly in having the ventral tubercles equal to the lateral ones, rather than smaller and more numerous. In this respect, the Grave Creek specimen is similar to *L. lyelli* (d'Orbigny), which has a much more inflated whorl section.

Material.—One fragment of about one-half whorl. U.S.N.M. No. 130184, from U.S.G.S. Mesozoic Locality 2190.

Age.—Probably late early to middle Albian.

Genus OXYTROPIDOCERAS Stieler, 1920

Type species—*Ammonites roissyanus* d'Orbigny, 1841

OXYTROPIDOCERAS? sp. indet.
Pl. 29, fig. 12

Discussion.—Small fragments only, the largest measuring about 15 mm., have been found on Grave Creek. These fragments show the typical compressed, high-whorled shape and ornamentation of *Oxytropidoceras*, and are questionably referred to that genus. The ribs are distinct, straight on the sides and strongly projected on the ventrolateral shoulder. The venter is compressed to form a thin, continuous keel. Suture unknown.

Material.—Four small fragments. Figured specimen, U.S.N.M. No. 130185, from U.S.G.S. Mesozoic Locality M-251.

Occurrence.—U.S.G.S. Mesozoic Localities 2190, M-251.

Age.—Probably late early to middle Albian.

Genus CLEONICERAS Parona and Bonarelli, 1896

Type species—*Ammonites cleon* d'Orbigny, 1850.

CLEONICERAS? DILLERI Jones, n. sp.
Pl. 29, figs. 5,13,14

Description.—Shell compressed, high-whorled, narrowly umbilicate; umbilical wall subvertical with angular rim; venter narrowly rounded. Early whorls apparently smooth to diameter of about 30 mm. where low, broad, obscure ribs appear on the outer two-thirds of the sides. Suture with asymmetric first lateral lobe, narrow first lateral saddle, and numerous auxiliary saddles.

Measurements.—(in mm.)

Specimen	Diameter	Height	Breadth	(B/H	Diam. of Umbilicus	Umbilicus/ Diameter %
Holotype U.S.N.M. No. 130179	61	34	14.5	0.41	7+	11+

Remarks.—*Cleoniceras? dilleri* n. sp. differs from typical *Cleoniceras* in its very weakly developed ornamentation and apparently smooth inner whorls. In this respect, it is closely related to *C.* (*Neosaynella*) *inornatum* Casey (1954, p. 106, fig. 3a,b, p. 109), except that *C.? dilleri* lacks the flattened venter on the early whorls.

C.? dilleri and *C. "cleon"* (Sinzow, 1909, pl. 2, figs. 3–5) are similar in ornamentation and whorl shape, but *C.? dilleri* has a narrower first lateral saddle and a longer first lateral lobe.

Holotype.—U.S.N.M. 130179.

Material.—One nearly complete specimen from U.S.G.S. Mesozoic Locality 2190.

Age.—Probably late early to middle Albian.

Class PELECYPODA
Genus INOCERAMUS Sowerby, 1814
Subgenus ACTINOCERAMUS Meek, 1876

Type species—*Inoceramus sulcatus* Parkinson, 1819.

INOCERAMUS (ACTINOCERAMUS) CONCENTRICUS Parkinson
Pl. 29, figs. 1,2

Inoceramus concentricus Parkinson, 1819, p. 58, pl. 1, fig. 4. Woods, 1911, p. 265, pl. 45, fig. 11; pl. 46, fig. 1–10; pl. 47, figs. 1,2.

Description.—Shell inequivalve, inequilateral, ovate; left valve moderately inflated; umbo anterior, pointed, incurved;

right valve smaller than left valve, nearly flat, umbo small; anterior margin concave to gently rounded; ventral margin broadly and asymmetrically rounded to meet the gently rounded posterior margin. Posterodorsal area forming a small, indistinct wing. Ornamentation consisting of weak asymmetrically curved, concentric ribs.

Material.—Five specimens; figured specimen, U.S.N.M. No. 130177, from U.S.G.S. Mesozoic Locality 2190.

Age.—Late early (?) to late Albian.

INOCERAMUS (ACTINOCERAMUS) SALOMONI d'Obigny
Pl. 29, figs. 3,4

Inoceramus salomoni d'Orbigny, 1850, p. 139. Woods, 1911, p. 263, pl. 45, figs. 3–7.

Description.—Left valve moderately inflated, inequilateral; outline subquadrate; length about equal to height; umbo anterior, pointed, curved inward and slightly forward; anterior side straight, truncated, concave beneath umbo, nearly perpendicular to plane between valves. A shallow, broad furrow extends from below umbo to the ventral margin on the anterior half of the valve. Ornamentation consists of weak, simple, concentric ribs. Right valve unknown.

Material.—Two specimens, left valves only. Figured specimen, U.S.N.M. No. 130178, from U.S.G.S. Mesozoic Locality 2190.

Age.—Probably middle Albian.

INOCERAMUS (ACTINOCERAMUS) "SUBSULCATUS" Wiltshire
Pl. 29, figs. 6,7

Inoceramus subsulcatus Wiltshire, 1869; p. 188, 190; *I. concentricus* var. *subsulcatus* Wilt., Woods, 1911, p. 268, pl. 47, figs. 3–14.

Description.—Similar to *Inoceramus concentricus* but with rounded, radial plications beginning at the ventral margin and extending toward, but not reaching, the umbo.

Material.—Two right valves. Figured specimen, U.S.N.M. No. 130180, from U.S.G.S. Mesozoic Locality 907.

Occurrence.—U.S.G.S. Mesozoic Localities 907, 2190.

Age.—Late early (?) to late Albian.

Genus MEGATRIGONIA van Hoepen, 1929
Subgenus APIOTRIGONIA Cox, 1952

Type species—*Trigonia sulcataria* Lamarck, 1819.

MEGATRIGONIA (APIOTRIGONIA) CONDONI (Packard)
Pl. 29, figs. 8–10,17,18

Trigonia condoni Packard, 1921; p. 28, pl. 8, fig. 2. *Trigonia packardi* Anderson, 1958, p. 108, pl. 1, fig. 5.

Description.—Shell pyriform, of moderate size, height equal to about two-thirds of length; beaks prominent, slightly anterior, curved inward, opisthogyrate. Anterior margin broadly rounded; ventral margin rounded; posterior portion elongate and sharply truncated. Dorsal region behind umbones slightly concave to nearly flat with dorsal ridge along plane of valves. Escutcheon small. Ornamentation on umbones consists of 10 to 15 distinct, rounded concentric ribs separated by rounded interspaces equal in width to the ribs; fine, oblique ribs present on posterior portion of umbones; ornamentation on flanks irregular; early ribs concentric posteriorly, but flexed downward toward the anteroventral margin anteriorly; later ribs trend posteroventrally from marginal carina, then bend abruptly toward anteroventral margin. Ornamentation on posterior of flanks consists of radiating ribs. Area unornamented except for distinct growth lines; bipartite, but median groove visible only on exfoliated specimens.

Remarks.—The exact locality from which Packard's holotype was obtained is not known, other than a "bed of one of the creeks emptying into Rogue River near Grants Pass" (Packard, 1921, p. 29). The only locality in the Grants Pass area where *M. condoni* is known to occur is on Grave Creek, so it is possible that this is the type locality.

Anderson's holotype of *M. packardi* from Texas Springs, California, is so poorly preserved that positive identification is impossible. However, an examination of topotype material indicates that *M. condoni* and *M. packardi* are conspecific.

Material.—Several hundred specimens.

Figured specimens, U.S.N.M. Nos. 130182, 130183, both from U.S.G.S. Mesozoic Locality 23542.

Occurrence.—U.S.G.S. Mesozoic Localities 907, 2190, 23542, 25230, M-251, M-252, M-253.

Age.—Early Albian to Cenomanian (?). No evidence exists that this species occurs in the Turonian as stated by Anderson (1958, p. 109).

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MANUSCRIPT RECEIVED JANUARY 31, 1959.

(*Explanation of Plate 29 follows*)

EXPLANATION OF PLATE 29

All figures natural size except as indicated

FIGS. *1,2—Inoceramus* (*Actinoceramus*) *concentricus* Parkinson. Left valve, side and anterior views, U.S.N.M. No. 130177.

3,4—Inoceramus (*Actinoceramus*) *salomoni* d'Orbigny. Left valve, side and anterior views, U.S.N.M. No. 130178.

5,13,14—Cleoniceras? dilleri Jones, n. sp. 5, suture of holotype at whorl height of 14 mm., ×3; *13,14*, anterior and side views of holotype, U.S.N.M. No. 130179.

6,7—Inoceramus (*Actinoceramus*) "*subsulcatus*" Wiltshire. Right valve, side and dorsal views, U.S.N.M. No. 130180.

8–10,17,18—Megatrigonia (*Apiotrigonia*) *condoni* (Packard). *8–10*, rubber cast left valve, anterior, and dorsal views, U.S.N.M. No. 130182; *17,18*, rubber cast, U.S.N.M. No. 130183.

11,15,16—Lyelliceras n. sp.? Side, ventral, and anterior views, U.S.N.M. No. 130184. ×2.

12—Oxytropidoceras? sp. indet. Side view, U.S.N.M. No. 130185, ×2.

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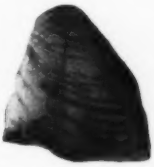
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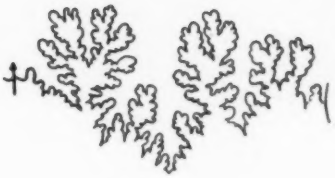
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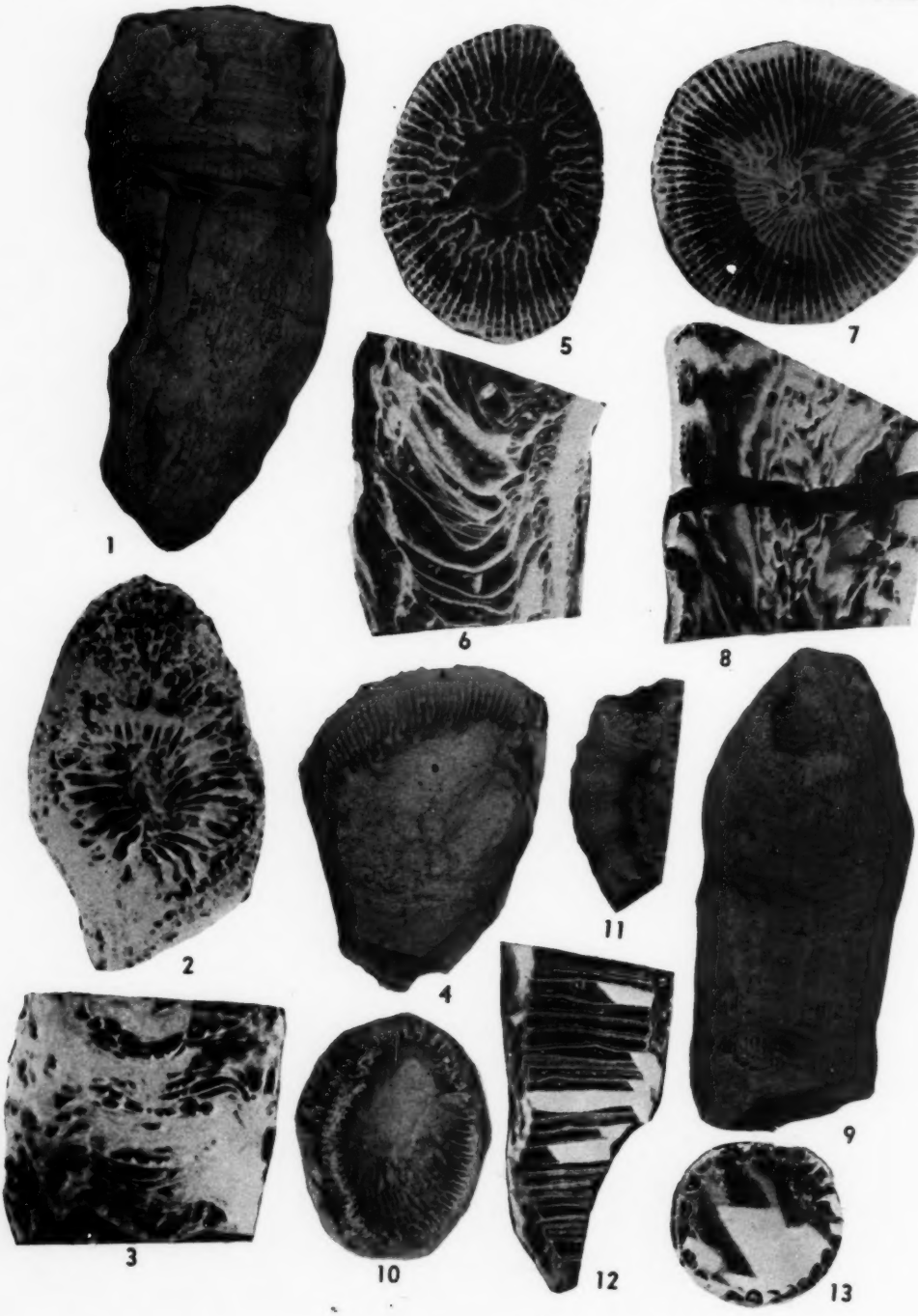
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JOURNAL OF PALEONTOLOGY, V. 34, NO. 1, P. 161–163, PL. 30, JANUARY, 1960

NEW RUGOSE CORALS FROM THE MIDDLE AND UPPER DEVONIAN OF NEW YORK

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Museum of Paleontology, University of Michigan

ABSTRACT—Two new species of rugose corals, *Macgeea ponderosa* and *Mictophyllum orientalis* are described from the Chemung group. The new species *Depasophyllum tabulatum* is described from the Tully limestone.

INTRODUCTION

CORALS are extremely rare in the clastic sediments typical of the New York Upper Devonian. A few specimens in the Cornell University collections were sent to me by Dr. J. W. Wells for study. In addition, some specimens from a small bioherm in the Tully limestone were sent. This paper is the result of the study of these specimens. I wish to thank Dr. Wells for the opportunity to study them. All type material is deposited in the collections of the Department of Geology, Cornell University.

SYSTEMATIC DESCRIPTIONS

Genus MACGEEA Webster

Macgeea Webster, 1889, p. 710; Fenton and Fenton, 1924, p. 53; Lang and Smith, 1935, p. 552; Smith, 1945, p. 27; Stainbrook, 1946, p. 419.

Type species.—By subsequent designation of Fenton and Fenton, 1924, p. 54, *Pachyphyllum solitarium* Hall and Whitfield, 1873, p. 232, pl. 9, figs. 6,7. Upper Devonian, Lime Creek shale, Cerro Gordo member, Iowa.

MACGEEA PONDEROSA n. sp.
Pl. 30, figs. 5–10

Description.—Corallum subcylindrical to ceratoid, the holotype, an incomplete specimen measuring 7 cm. long with an average diameter of 3 cm. with proximal end missing. Exterior with a thin epitheca through which the septal ridges are prominently developed. Calyx round, oval, or constricted with erect, relatively thick walls and a flat base.

In transverse section septa radially arranged, averaging about 96 in number. Major septa extending almost to axis, dilated peripherally and axially, attenuated periaxially. Minor septa about one-third as long as major, dilated peripherally, attenuated axially. In longitudinal section tabulae occupying axial region, complete or incomplete, typically proximally convex, spaced from 1 to 3 mm. apart. A peripheral row of distally convex, globose dissepiments present, bounded periaxially by several rows of elongate, axially convex dissepiments.

Remarks.—*Macgeea ponderosa* is distinguished from other species of the genus by

EXPLANATION OF PLATE 30

FIGS. *1–4*—*Mictophyllum orientalis* n. sp. *1*, side view of holotype No. 40601 ×1; *2,3*, transverse and longitudinal sections of same specimen ×1.5, from lower part of Chemung sandstone, Spencer, Tioga County, New York. *4*, Latex cast of calyx of paratype No. 40602, lower part of Chemung sandstone at "The Narrows," a cliff 1 mile west of Chemung, Chemung County, New York.

5–10—*Macgeea ponderosa* n. sp. *5,6,9* Transverse section and longitudinal section ×1.5, and exterior of holotype ×1, No. 40598, lower part of Chemung sandstone, cliff above Chemung River, just west of Waverly, Tioga County, New York. *7,8*, Transverse and longitudinal sections ×1.5, of paratype No. 40599 from same horizon and locality as holotype. *10*, Latex cast of calyx ×1, of paratype No. 40600, from lower part of Chemung sandstone, Spencer, Tioga County, New York.

11–13—*Depasophyllum tabulatum* n. sp. *11*, Side view of paratype ×1, No. 40603; *12,13*, Longitudinal and transverse sections ×2, of holotype No. 40604, both from Tully limestone, reef knoll, southeast of Borodino, Onondaga County, New York.

its much greater size, larger number of septa, and by the proximally convex tabulae.

Occurrence.—Upper Devonian, lower part of Chemung sandstone, western New York.

Types.—Holotype, Cornell Univ. no. 40598; paratypes, nos. 40599–60.

Genus *Mictophyllum* Lang and Smith

Mictophyllum, Lang and Smith, 1939, p. 155; Smith, 1945, p. 30.

Type species.—By original designation, *Mictophyllum nobile* Lang and Smith, 1939, p. 155, pl. 4, figs. 1a–d, Upper Devonian Red Knife River, North West Territories, Canada.

MICTOPHYLLUM ORIENTALIS n. sp.
Pl. 30, figs. 1–3

Description.—Corallum simple, narrowly ceratoid. Holotype, with broken proximal end and somewhat crushed distal end, measuring 7.5 cm. long with an average maximum diameter of 3 cm. Exterior with a heavy, closely annulated epitheca through which weakly developed, widely separated interseptal ridges are developed. Calyx of holotype filled with rock material but one partly preserved on paratype indicates walls thin and erect.

In transverse section major septa 32, thin peripherally, becoming very thickened periaxially and slightly attenuate axially, extending without twisting almost to axis. Minor septa very short and thin lacking in some areas. In longitudinal section tabulae occupying most of corallite, closely set, complete and incomplete, relatively horizontal or slightly proximally convex in the axial region, becoming distally convex in the periaxial region, and bending downward at the periphery. Dissepimentarium very narrow, composed of one or two rows of large, very elongate dissepiments.

Remarks.—This species most nearly resembles *M. semidilatum* Smith (1945, p. 31, pl. 4, figs. 2a–c) in its septal arrangement but differs in the very restricted dissepimentarium.

Occurrence.—Upper Devonian, lower Chemung sandstone, Spencer, Tioga County, New York.

Types.—Holotype, Cornell Univ., no. 40601; paratype, no. 40602.

Genus DEPASOPHYLLUM Grabau

DEPASOPHYLLUM TABULATUM n. sp.
Pl. 30, figs. 11–13

Description.—Coralla typically simple, cylindrical, largest known specimen, incomplete, measuring 3 cm. in length with an average diameter of 1 cm. Exteriors with a closely annulated epitheca. Calyxes unknown.

In transverse section septa 24, of equal length, very thin, extending less than one-third distance to axis.

In longitudinal section tabulae typically complete, closely set, horizontal in axial and periaxial regions, becoming sharply deflected downward near periphery.

Remarks.—This species is similar to the type species *D. adnetum* Grabau but differs in having fewer septa and more closely set tabulae (see Ehlers & Stumm, 1949, for illustrations of type species). No compound specimens of *D. tabulatum* have been found.

Occurrence.—Middle Devonian, Tully limestone, New York.

Types.—Holotype, Cornell Univ. no. 40603; paratype, no. 40604.

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JOURNAL OF PALEONTOLOGY, V. 34, NO. 1, P. 164–167, 2 TEXT-FIGS., JANUARY, 1960

AGE AND FAUNAL RELATIONSHIP OF *TAPIRAVUS* REMAINS FROM FLORIDA

STANLEY JOHN OLSEN

ABSTRACT—*Tapiravus* remains are known from three widely separated localities in the eastern United States. Sufficient material from the Bone Valley deposits of peninsular Florida, is now known to warrant establishing this genus of tapirs as occurring in Florida during the upper Miocene or lower Pliocene times and in recording the type description of *Tapiravus polkensis*.

INTRODUCTION

PERHAPS no area in Florida has caused as much concern, with regard to dating the vertebrate fauna it contains, as has the Bone Valley of Polk County, Florida. The term "Bone Valley" should be used to define a geographic boundary, rather than a stratigraphic unit, as beds ranging from middle Miodene through the lower Pleistocene are known to occur in the "Bone Valley" as defined by earlier workers. There has been considerable confusion and even altered opinions among previous workers as to the age determinations of these beds. Evaluation of work done by the state and federal surveys is now in progress and it is hoped that a solution, agreeable to most of those concerned with this problem, will be forthcoming in the not too distant future.

Due to the present methods of phosphate mining, it is not possible to determine the exact horizon from which a specimen is recovered. Dating these remains is a difficult and hazardous practice unless the forms under surveillance are known from other horizons of known age. Recorded *Tapiravus* remains have a limited distribution in time and they are known from the Bone Valley area as well as from beds of middle Miocene age elsewhere along the eastern coast of the United States. However, Schlaikjer (1937) hypothesized that *Tapiravus* may extend up into the upper Miocene and lower Pliocene, and it is very probable that the Florida material is from these higher beds.

Dr. T. E. White (1942) questionably recorded this genus from the phosphate beds of Polk County, Florida, but hesitated to go beyond this category in his brief description of these remains. The genus *Tapiravus* as set up by Dr. O. C. Marsh (1877) was not clearly defined and some confusion exists as to the exact species used by Marsh to designate this new animal from the Miocene of New Jersey. Dr. E. M. Schlaikjer, in his contribution on the lower Miocene tapirs, gives a satisfactory explanation of this error in Marsh's taxonomy and sums up the generic difference which separates *Tapiravus* from the modern *Tapirus* as being only that of size, the later genus being considerably larger (Schlaikjer, 1937). Dr. C. L. Gazin reported and described additional specimens of this little known form. This material extended the range of *Tapiravus* into the Miocene of Maryland (Gazin and Collins, 1950).

Gazin added more evidence for the generic separation of *Tapiravus* from *Tapirus* by noting that the maxilla, though smaller, is relatively deeper when the lengths of the cheek tooth series are considered. Also, the outward face of the lackrymal is less modified than in the living genus, though actually nearly as long, and the lachrymal processes are not nearly so prominent. The sulcus on the lateral face of the ascending portion of the maxilla is shallow and confined to the maxilla and probably the frontal, whereas in *Tapirus* this sulcus is much more deeply impressed, involving the lachrymal bone, and may extend as far down as the intraorbital foramen.

Material collected subsequent to White's note is of sufficient quality to warrant recording this genus, with some surety, as coming from the upper Miocene or lower Pliocene beds in peninsular Florida.

SYSTEMATIC DESCRIPTION

Family TAPIRIDAE Burnett 1830

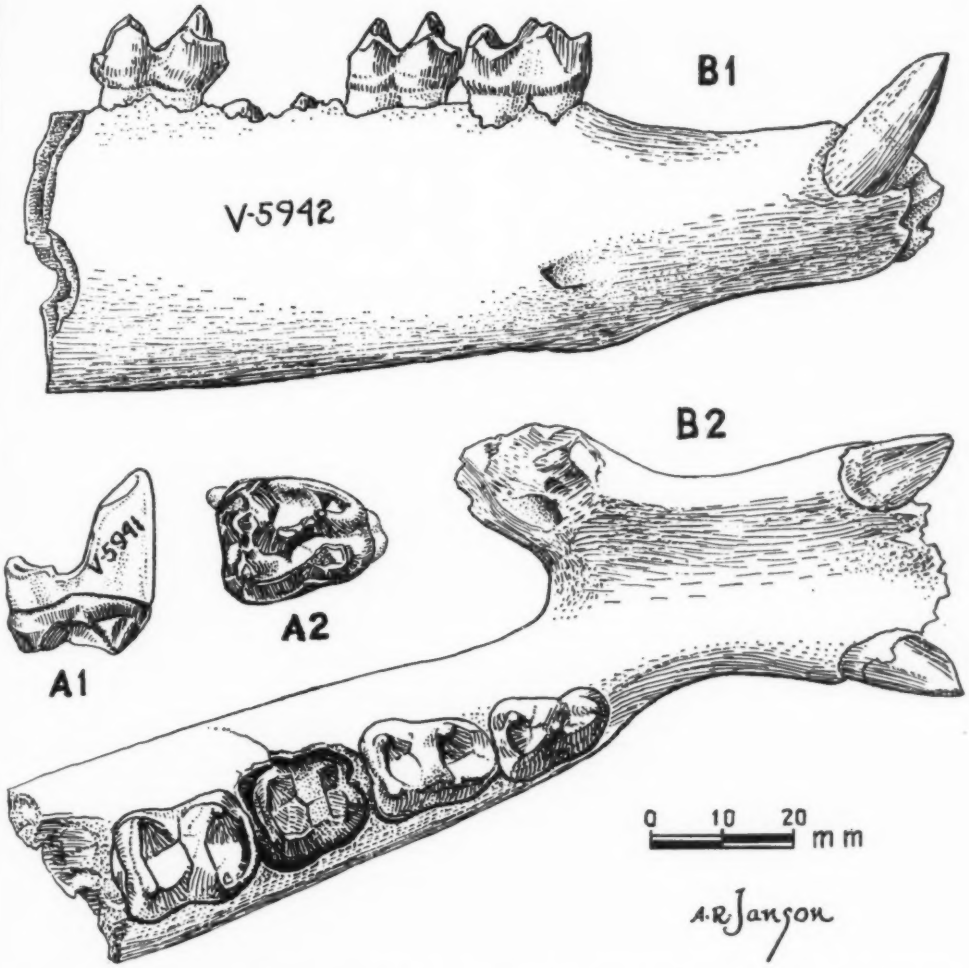
Genus TAPIRAVUS Marsh 1877

TAPIRAVUS POLKENSIS[1] n. sp.

Text-fig. 1

Tapiravus (?) White, 1942, p. 87–91, pls. 16–18.
Tapiravus sp. Sherman, 1952, p. 86–126.

[1] Named for Polk County, Florida, an area from which many vertebrate fossils have been collected during this century.



TEXT-FIG. *1—Tapiravus polkensis*, type F.G.S. V-5941: A-1, posterior face of left P^4; A-2, occlusal surface of left P^4. Paratype F.G.S. V-5942: B-1, labial view of symphysis and right ramus with C and P_2-M_1; B-2, occlusal view of same specimen.

Horizon and locality: Upper Miocene—lower Pliocene, phosphate pit of American Agricultural Chemical Company, Pierce, Polk County, Florida.

Type: Florida Geological Survey, V-5941, upper left P^4.

Paratype: Florida Geological Survey, V-5942, symphysis of lower jaw with canines and right P_2—M_1.

Referred specimen: Museum of Comparative Zoology, Harvard University 3808, fragment of left mandible with M_2—M_3.

Material used for comparison: Yale Peabody Museum 13474, *Tapiravus validus* (type), left P^4; United States National Museum 18372, *Tapiravus* cf. *validus*, fragmentary maxilla with P^3—M^1; United States National Museum 21377, *Tapiravus* cf. *validus*, right ramus with M_2, M_3; Museum of Comparative Zoology, Harvard University 2949, *Miotapirus harrisonensis* (type), upper and lower dentitions; also recent *Tapirus* material.

Formal diagnosis: External posterior corner of P^4 projects proportionally in a more lateral direction in *Tapiravus polkensis* than it does in *Tapiravus validus* or *Tapirus*. The posterolingual border of P^4 is more rounded compared with a more square outline that is found in the other species of

Tapiravus. Dentition is intermediate in size between *Tapiravus validus* and *Tapirus terrestris*.

The type description of the species of *T. validus* defines the specimen as a "first true molar of the left upper jaw" (Marsh, 1871). Schlaikjer (1937) refers to this same tooth as the "genoholotype is a single upper tooth, either P^4 or M^1. . . ." On comparison of the type of *Tapiravus validus* with similar teeth exhibited in members of the existing genus *Tapirus* and with the upper dentition of *Miotapirus harrisonensis*, the writer believes that this tooth, as well as the type of *Tapiravus polkensis* represents an upper left P^4. Identification of separate teeth in tapirs is difficult as P_4 are nominally molariform and the entire series of P_2 through M_3 function as a unit without any distinct localization of function within this cheek region, such as occurs in the carnivores or among many other mammals, including some ungulates (Simpson, 1945). P^4 in the tapirs does differ from M^1, the next tooth in line, by having the external posterior corner extend in a more lateral direction. *Tapiravus validus* has a narrower anteroposterior diameter when compared with the lingual-labial diameter of the occlusal surface of this tooth. Cusp arrangement is the same in *Tapiravus validus* and *T. polkensis*, even to the distinctive cingulum present on the posterolingual border. P^4 is missing in the Maryland specimen (U. S. N. M. 18372) but the teeth that are preserved, P^3 and M^1, are considerably smaller than the Bone Valley specimen. In recent tapirs, the greatest width and length of P^4 are nearly equal (text-fig. 2).

Although White (1942) did not figure the specimen he referred to *Tapiravus* (?) (M. C. Z. 3808), he speaks of the dentition being Dp_{2-3} and goes on to state, "In size and in form of the teeth it compares very well with a specimen of *Tapirus bairdii* which has only the milk dentition." When this same fossil is compared with the other specimens of the lower dentitions of Miocene tapirs, it is apparent that the teeth represented are the permanent lower molars. X-rays of the paratype of *Tapiravus polkensis* (F. G. S. V-5942, text-fig. 1) show that this jaw has no deciduous teeth and that the teeth preserved are C and P_2—M_1. Dm_4 has just been lost and P_4 is erupting. There are no replacement teeth under any of the cheek teeth so they most certainly are permanent teeth. M_1 is determined both by the state of wear and from the proportions; narrower than the preceding tooth and with the anterior loph distinctly wider than the posterior, whereas on P_4 in tapirs the lophs are about equal or the posterior is wider. Tapirs replace dm_4 rather late and a recent tapir of the same dental age as F. G. S. V-5942 would be full-grown (Simpson, personal communication).

BIOSTRATIGRAPHY

Gazin (1950) in his report on the land mammals of the Miocene of the Chesapeake Bay region reviewed the stratigraphic occurrence of Marsh's type, and the writer believes, correctly correlated the Kirkwood

REFERRED SPECIMENS	$P^{\overline{4}}$ ANTEROPOSTERIOR DIAMETER	$P^{\overline{4}}$ GREATEST TRANSVERSE DIAMETER	$M_{\overline{2}}$ ANTEROPOSTERIOR DIAMETER	$M_{\overline{2}}$ GREATEST TRANSVERSE DIAMETER	$M_{\overline{3}}$ ANTEROPOSTERIOR DIAMETER	$M_{\overline{3}}$ GREATEST TRANSVERSE DIAMETER
Tapiravus validus (type) Y.P.M. 13474	14.5 mm.	18.5mm.	----	---	----	---
Tapiravus cf. validus U.S.N.M. 21377	----	---	17mm.	12mm.	16mm.	11.5mm.
Tapiravus polkensis (type) F.G.S. V-5941	17mm.	22mm.	----	---	----	---
Tapiravus polkensis M.C.Z. 3808	----	---	19mm.	12.5mm.	17.5mm.	13mm.
Tapirus terrestris A.M.N.H. 45	20mm.	21.5mm.	21mm.	16mm.	23mm.	17.5mm.

TEXT-FIG. 2—Comparative linear measurements of the known teeth of *Tapiravus polkensis*, *Tapiravus validus* and *Tapirus terrestris*.

formation of New Jersey as being equivalent to the Calvert formation of Maryland, both being middle Miocene in age. The beds that have been termed the Bone Valley formation exhibit considerable lithological change and with the exception of the Bone Valley gravels are not mappable units. It is apparent that the beds that are termed Bone Valley lose their right to be termed a formation. When a complete faunal list is compiled of those animals that are known from the Bone Valley, it is established that they actually range from the Miocene on through the Pleistocene and may include several formations. The mammals, *Leptarctus* and *Hoplocetus*, are known only from the Miocene elsewhere. The mammals *Agriotherium*, *Hipparion*, *Nannipus*, *Neohipparion*, *Megatylopus*, *Hexameryx*, *Felsinotherium*, *Kogiopsis*, *Balaenoptera* and *Megatherium* occur elsewhere only in the Pliocene with the exception of *Megatherium* which survived into the Pleistocene. The mammals *Osteoborus*, *Serridentinus*, *Rhynchotherium*, *Teleoceras*, *Aphelops*, *Prosthenops* and *Procamelus* are known elsewhere as occurring both in the Miocene and the Pliocene. Since the known collections of the above genera of mammals are all from the same general area in Polk County and the remains have been recovered from sediments whose exact stratigraphic position are unknown, it is not possible to definitely state to which of these groups *Tapiravus polkensis* is faunally associated. However, the writer believes that it is not unreasonable to assume, on the evidence of the existing *Tapiravus* remains from Central Florida, that *Tapiravus polkensis* represents an intermediate form between *Tapiravus validus*, from the middle Miocene, and *Tapirus terrestris*, from the Pleistocene, and is from that portion of the Bone Valley beds designated as upper Miocene or lower Pliocene in age.

Although a host of forms have been reported from lower Miocene localities in northern Florida, no tapir remains have been found in these localities. This is particularly true of the Thomas Farm fossil quarry, which has yielded thousands of Miocene perissodactyl remains during the last quarter of a century.[2] This may or may not be significant for tapir remains are not common in those localities from which they are known.

[2] Romer, 1958, and personal observation subsequent to this publication.

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I wish to express my thanks to Dr. G. G. Simpson for generously helping me with this problem by obtaining X-rays of the paratype and by interpreting the dental series of this specimen.

Thanks are also due to Mrs. R. H. Nichols and Dr. H. E. Wood II, of the American Museum of Natural History, as well as Dr. C. L. Gazin, of the United States National Museum, and Prof. Bryan Patterson, of the Museum of Comparative Zoology for aiding me in obtaining casts of material needed for comparison.

Permission to undertake this study was granted by Dr. Robert O. Vernon, Director of the Florida Geological Survey.

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CAMBRIAN AND ORDOVICIAN LORICATES FROM NORTH AMERICA

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ABSTRACT—Five new species, one new genus and one new family of late Cambrian and early Ordovician loricates are described. The new family *Preacanthochitonidae* contains the new genus *Preacanthochiton* with the new species *P. cooperi*, *P. depressus* and *P. productus*. In addition the new species *Chelodes intermedius* and *C. depressus* are described. Although the collection consists of separated plates, a formula is developed that gives a close approximation of the length of the complete animal. The morphological and systematic discussions are followed by general remarks on the origin and evolution of the loricates. A preliminary synoptical table of the class Loricata and a list of references completes the paper.

INTRODUCTION AND ACKNOWLEDGMENTS

EXAMINATION of the fossil material used for this paper was made in the Paleontological Department of Lund University mainly at my own expense.

From the foundation "Konung Gustaf VI Adolfs 70-årsfond för Svensk Kultur" I received a sum of money for facilitating my examination. To the board of His Majesty's Foundation I express my great gratitude. The "Åke Wibergs Stiftelse" Foundation, Kil, also granted me a sum for which I am indebted to Mr. Åke Wiberg, first commissioner and proprietor of Apertin estate.

The fossil material examined was sent from the Smithsonian Institution, Washington, D. C. To the Head Curator of the Department of Geology, Smithsonian Institution, Dr. G. Arthur Cooper, I express gratitude for loan of the collection. I express my thanks to the Director of the Paleontological Department of Lund University, Professor Gerhard Regnell, who has been generous in helping me in many ways.

I thank also my friend Mr. Axel Roseen, headmaster at Kil, for linguistic supervision of the manuscript, and Mrs. G. Sarnäs, artist at Malmö, for preparing the illustrations. The late Director of the Paleontological Department, Lund University, Professor Gustaf T. Troedsson, who facilitated my work in many ways, I remember with sincere gratitude.

METHODS OF STUDY

The usual tools used in paleozoological preparations were employed in this investigation. I have not been able, however, to use the section method of Sollas-Stensiö, because I did not have permission to cut the fossils into sections. By making reconstructions of the species described I introduced a new method: first, I built cardboard-models of the animals, and then the models were reproduced by drawings.

EXPLANATION OF TERMS

Anterior terminal valve = "head" valve.
Posterior terminal valve = "tail" valve.
Body valves = the valves situated between the two terminal valves.
Periostracum = the outermost layer of the valves.
Tegmentum = the next outermost layer of the valves.
Articulamentum s.s. = the shell layer between the tegmentum and the hypostracum.
Hypostracum = the innermost layer of the valves.
Tegmental areas = the fields or regions into which the surface of the tegmentum by advanced forms is differentiated.
Area apicalis = the part of the periostracum and the tegmentum which is curved around the posterior margin of a valve to the ventral surface of the valve.
Perinotum = the girdle of soft tissues surrounding the whole shell of the living animal.
Apex = the beak-shaped part of the posterior margin of the body valves.
Mucro = the elevated tegmental part of the posterior terminal valve.

Jugal angle = the angle between the two halves of the body valves.

Total covering exists when the posterior margin of a valve covers the whole anterior margin of the next posterior valve.

Partial covering exists when the posterior margin of a valve covers only a small middle part of the anterior margin of the next posterior valve.

Jugal covering exists when the apex only gets into contact with the anterior margin of the next posterior valve.

S. I. = Smithsonian Institution, Washington.

LOCALITIES

100i Upper Cambrian (Eminence formation), 5 mi. northwest of Eminence, Shannon County, Missouri.

101v Lower Ordovician (Upper Gasconade formation), Hahatonka Springs, 1¼ mi. north of Decaturville, Camden County, Missouri.

102f Upper Cambrian (Eminence formation), Eminence, Shannon County, Missouri.

261k Upper Cambrian (Eminence formation), 1½ mi. below Timber, in bluff along Sinking Creek, Shannon County, Missouri.

261n[1] Upper Cambrian (Eminence formation), low in formation, a few feet above porphyry, Jerktail Mine, head of small tributary of Thompson Creek, NE ¼ sec. 5, T. 29 N., R. 3 W., 7 mi. northeast of Eminence, Shannon County, Missouri.

261o Upper Cambrian (Eminence formation), top of hill on road to Winona, 3 mi. south of Eminence, Shannon County, Missouri.

399c Upper Cambrian (lower Eminence formation), trilobite beds, Little Indian Creek, 2½ mi. above mouth of creek, 6 to 7 mi. (airline) south of St. Clair, Franklin County, Missouri.

416c Lower Ordovician (Chepultepec formation, 1000 feet below *Ceratopea*) at top of path from office to tunnel, Natural Tunnel, Scott County, Virginia.

436b Upper Cambrian (Eminence formation), north side of river, less than one mile east of ford over Jacks Fork at Eminence, Shannon County, Missouri.

438t Lower Ordovician (Gasconade formation), 2½ mi. above mouth of Little Indian Creek of Merrimac River, 10½ mi. southwest of St. Clair, Franklin County, Missouri.

453e Upper Cambrian (Eminence formation), near contact of porphyry near Flip, 8 mi. southeast of Eminence, Shannon County, Missouri.

453-l Upper Cambrian (Eminence formation), NE. ¼ NE. ¼ sec. 17, T. 37 N., R. 2 E., about 3 mi. east of Potosi, Washington County, Missouri.

453n Lower Ordovician (Gasconade formation), top of hill on Ellington road, 2½ mi. south of Centerville, Reynolds County, Missouri.

453p Upper Cambrian (Eminence formation), SE. ¼ NE. ¼ sec. 24, T. 37 N., R. 1 E. southwest base of large hill on Shirley road, 4½ mi. west of Potosi, Washington County, Missouri.

453y Upper Cambrian (Eminence formation), one mile east of Berryman, Crawford County, Missouri.

455u Lower Ordovician (Gasconade ? formation), west of Castor River (on west side of fault), one mile west of Higdon, Madison County, Missouri.

455v Upper Cambrian (near top of Eminence formation), near top of south slope of hill, 4¾ to 5 mi. south of Potosi, Washington County, Missouri.

455v[1] Upper Cambrian (Van Buren formation), near top of south slope of hill, 4½ to 5 mi. south of Potosi, on Caledonia road, Washington County, Missouri.

479a Lower "Ozarkian"—Upper Cambrian, south side of hill north of Mrs. Josie A. Hall's house, Whitehall, Washington County, New York.

2464co Lower Ordovician (Longview formation, 1000 feet below *Ceratopea*), 3 mi. northwest of Middletown, Frederick County, Virginia.

SYSTEMATIC DESCRIPTIONS

Class LORICATA

Subclass PALEOLORICATA

Order CHELODINA

Family PREACANTHOCHITONIDAE, n. fam.

Diagnosis.—Sculpture similar to that of *Acanthochites* Risso. The circumference of the body valves variable, heart-like, broad or narrow rectangular. Type-genus, *Preacanthochiton* n. gen.

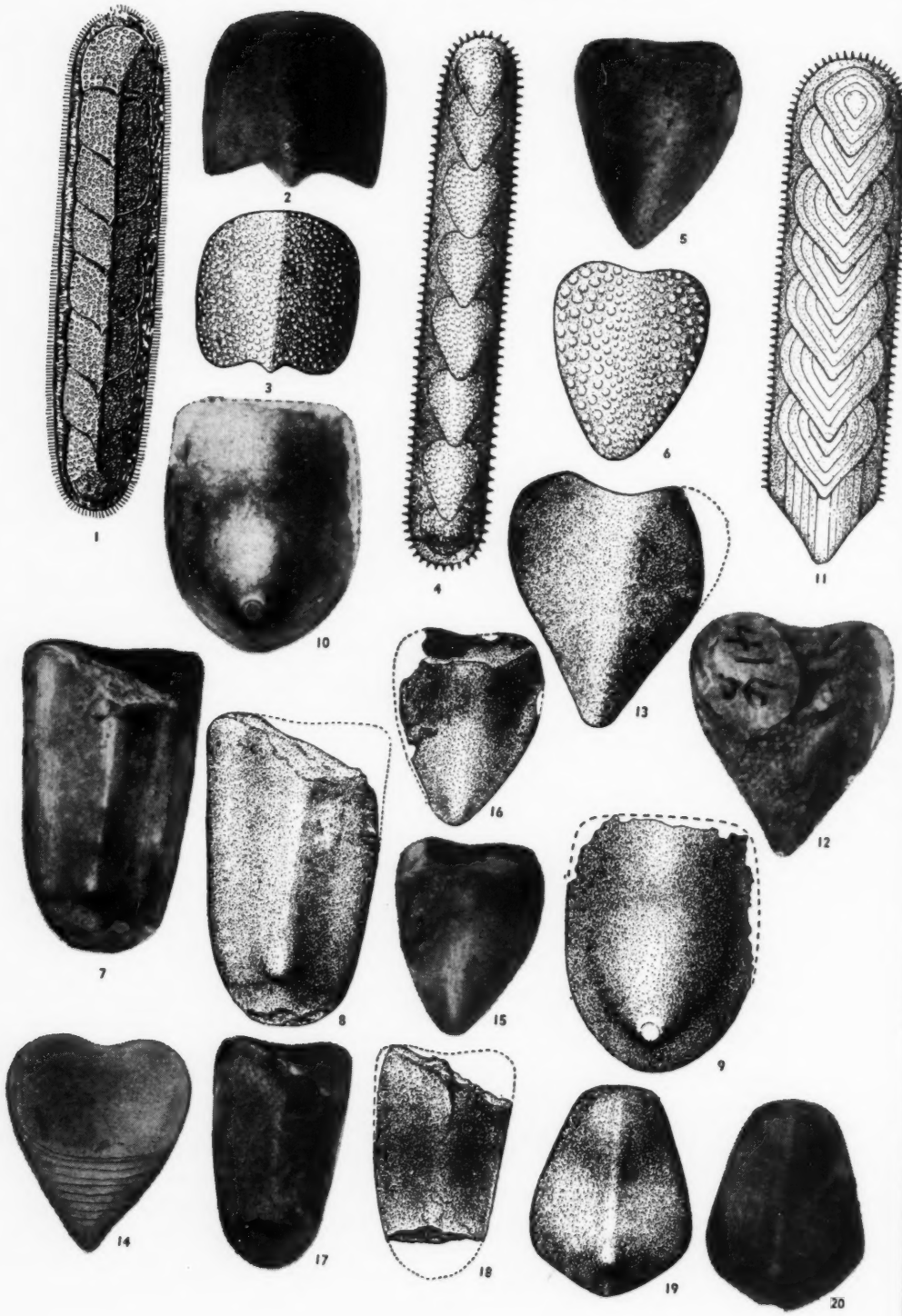
Genus PREACANTHOCHITON Bergenhayn, n. gen.

Diagnosis.—Sculpture consisting of small rounded pustules. Circumference of body valves heart-shaped or rectangular with rounded lateral margins. Covering total or partial.

Type species.—*Preacanthochiton cooperi* n. sp.

PREACANTHOCHITON COOPERI, n. sp. Text-fig. 1—1–3

Diagnosis.—The form of the circumfer-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ence of the body valves suggesting that of the tegmentum of *Acanthochiton acutirostris* (Reeve) (according to Pilsbry 1893). Each half of the body valves straight and the jugal angle about 90°. Mucro strongly elevated and situated behind the centrum of the valve.

Localities in Missouri and material.—261k, 1 posterior terminal valve and 1 impression of an anterior terminal valve; 436b, 1 posterior terminal valve; 453e, chert 1 impression of the tegmental surface of an anterior terminal valve; 453-l, 14 specimens; 453n, 2 specimens; 453p, 9 specimens; 453y, 11 specimens; 455u, 2 specimens; 455v, 25 specimens.

Geological age.—Upper Cambrian: localities 261k, 436b, 453e, 453-l, 453p, 453y, 455v.

Lower Ordovician: localities 452n, 455u.

Type.—Holotype, the figured body valve USNM 137370.

Description.—As already mentioned the circumference of the body valves has a form resembling that of the tegmentum of *Acanthochites acutirostris* (Reeve). The posterior margin on both sides of the apex is very strongly emarginated, and the halves of the body valves are quite straight or a little concave, forming an angle of about 90°. The strongly elevated mucro is very characteristic of the species. The posterior terminal valve varies slightly in shape. In some specimens the jugal part of the valve as well as the posterior one is straight. In some the jugal part is concave and the posterior part slightly convex, and in others the jugal part is straight and the posterior part nearest the mucro is concave. The mucro proper is drawn out in the last mentioned valves forming a short hollowed cone. In the living animals these hollows were possibly filled with a muscle which attached the valve to the posterior part of the foot. This varying structure of the valve proves that the species, in the shape of the posterior terminal valve, was in an experimental stage, so to speak. These circumstances are remarkable because the body valves in their shape must be designated as rather advanced. In this extinct species, as in some recent ones, the body valves and the posterior terminal valve represent different levels of development.

The sculpture consists of very small rounded pustules, which, together with the interposed narrow tegmental ridges, give the surface of the tegmentum a reticulated appearance. Tegmental areas are not developed, but the sculpture of the sides of the body valves is more distinct than on their jugal parts. This depends on the fact that the granulae on the jugal parts of the valves are much smaller than those on the lateral parts. Therefore the surface of the body valves has almost the same appearance as *Acanthochites*.

It is natural to suppose that the development of the distinct areae lateropleurales and areae jugales (Bergenhayn 1930b) in

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TEXT-FIG. *1—1–3, Preacanthochiton cooperi* Bergenhayn, n. sp. (*1*) reconstruction; (*2*) body valve in dorsal view, ×7.5, holotype USNM 137370; (*3*) same body valve in dorsal view, ×7.5, loc. 453-l.

4–6, Preacanthochiton depressus Bergenhayn, n. sp. (*4*) reconstruction; (*5*) body valve in dorsal view, ×7.5, holotype USNM 137372, loc. 101v; (*6*) same body valve in dorsal view, ×7.5.

7,8, Preacanthochiton productus Bergenhayn, n. sp. (*7*) posterior terminal valve in dorsal view, ×3, holotype USNM 137373, loc. 261n; (*8*) the same valve in dorsal view, ×3.

9,10, Preacanthochiton n. sp. aff. *P. cooperi* Bergenhayn, (*9*) posterior terminal valve in dorsal view, ×7.5, figured specimen, USNM 137374, loc. 399c; (*10*) same terminal valve in dorsal view, ×7.5.

11, Chelodes intermedius Bergenhayn, n. sp. (*11*) reconstruction.

12–14, Chelodes intermedius Bergenhayn, n. sp. (*12*) body valve in dorsal view, ×2, holotype, USNM 137375, loc. 416c; (*13*) same body valve in dorsal view, ×2; (*14*) same body valve in ventral view, ca. ×2.

15,16, Chelodes depressus Bergenhayn, n. sp. (*15*) body valve in dorsal view, ×3.5, holotype, USNM 137376, loc. 438t; (*16*) the same, ×3.5.

17,18, Chelodes ? sp. indet. (*17*) posterior terminal valve in dorsal view, ×2. figured specimen USNM 137378, loc. 438t; (*18*) same body valve in dorsal view, ×2.

19,20, Priscochiton ? sp. indet. (*19*) posterior terminal valve in dorsal view, ×4.5, figured specimen USNM 137377, loc. 479a; (*20*) same in dorsal view, ×4.5.

the acanthochitonid forms started with small tubercles on the jugal part and larger ones on the lateral parts of the valves. In about the same manner the pustules on the body valves in *Preacanthochiton cooperi* are developed too. But if one assumes this, it is also plausible to derive the preacanthochitonid sculpture-type from a still primitive sculpture-type characterized by pustules quite equal in size and shape on the whole tegmental surface (cf. Bergenhayn 1955 p. 30–31). Judging from an impression of the tegmentum of one anterior terminal valve, the granules were of the same size and shape on all parts of the surface excepting those of the apex, which are slightly smaller. So also are the granules of the jugal part of the posterior terminal valve compared with those of the other parts of the valve. Therefore this jugal part shows a smoother surface than the other parts of the tegmentum.

In an earlier paper the author derived a formula for calculation of the length of the whole shell (Bergenhayn 1955). If the average length of each body valve is m millimeters and the average length of that part of a valve which is covered by the nearest anterior valve is n millimeters and the shell of a specimen consists of p valves one obtains the formula for calculation of the length L of the shell: $L=m\ (p-2+\sqrt{2})-n(p-2)$. For the calculation of the quotient Q of the length and breadth of the shell the formula $Q=L/b$ is derived where L is the length of the shell and b is the distance between the lateral margins of the body valves. The values of L and Q, which one gets by application of these formulae, are mathematically only approximate.

With regard to the mathematical value of the factors m, n and b, that of n is most difficult to settle. As a general rule, however, it is valid that the length of n is equal to the length of the area apicalis.

For the holotype $m=4.5$ mm., $n=0.3$ mm., $b=4.3$ mm. and p supposed to be 8.

$$\therefore L=4.5(8-2+\sqrt{2})-0.3(8-2)\text{ mm.}=31.56\text{ mm.}$$

and

$$Q=\frac{31.56}{4.3}=7.34.$$

Consequently the shell was about 31 mm. in length and nearly 7 times as long as broad.

Another body valve USNM 137369 from locality 453n, $m=5.5$ mm., $n=0.5$ mm. and $b=5.3$ mm.

$$\therefore L=5.5(8-2+\sqrt{2})-(8-2)0.5=37.977\text{ mm.}$$

and

$$Q=\frac{37.777}{5.3}=7.197.$$

This shell accordingly was about 37 mm. in length and like the previous one 7 times as long as broad.

Owing to the value of Q of the two shells they must be considered as longish-oval (von Middendorf 1848; Bergenhayn 1930a). In this connection I take the opportunity to point out that in most of the described Paleozoic loricates the value of Q is rather high. Consequently they were thin and usually "vermiform." The older and therefore larger specimens proportionately are thinner than younger ones.

In the before mentioned paper (Bergenhayn 1955), the geologically oldest and anatomically typical formgroup in every one of the six orders of the loricates has been termed "Anfangsform der Ordnung." It is also supposed that the "Anfangsformen" were developed from still more primitive formgroups, termed "Stammformen der Ordnungen." In the paper in question it is also pointed out that "die Stammformen der neoloricaten Ordnungen müssen innerhalb der Ordnung *Chelodina* ihre systematischen Positionen haben." In the same paper it is also asserted that the "Stammformen" were hypothetical except for the "Stammform" of the order *Acanthochitonina*. "Als die Stammform der Ordnung *Acanthochitonina* oder wenigsten eine Form mit nahen genetischen Beziehungen zu der fraglichen Stammform ist eine neue Art zu betrachten, die in einer zukünftigen Arbeit unter dem Namen *Preacanthochiton cooperi* beschrieben werden soll."

It will be more correct, however, to consider the species as a form which is nearly related to the primitive "Stammform," than to regard it as the "Stammform" proper. Certainly the species are very primitive with regard to the structure of the shell. With regard to the jugal sculpture not quite agreeing with the remaining parts of the shell and the peculiar shape of the posterior terminal valve, the species, in spite of its great age, is somewhat too specialized to be

considered as the primitive "Stammform" of the order. These circumstances, however, do not upset the probability that the "Stammform" of the order *Acanthochitonina* is to be found in that systematic category which is represented by the family Preacanthochitonidae.

PREACANTHOCHITON DEPRESSUS, n. sp.
Text-fig. 1—4–6

Diagnosis.—The body valves wedge-shaped, dorso-ventrally depressed. The sculpture consisting of small rounded pustules.

Localities in Missouri and material.—453n, chert. 1 posterior terminal valve. 101v, 1 body valve and 1 impression of the dorsal side of the same valve.

Geological age.—Lower Ordovician, locality 101v, 453n.

Type.—Holotype, the figured body valve USNM 137372.

Description.—Body valves broadly heart- or wedge-shaped. In consequence of the shape of the valve the covering was jugal and the perinotum certainly was rather thick and wide. Area posterior depressed and the mucro situated somewhat posterior. The anterior terminal valve is not known, but presumably its anterior part was oval and its posterior part triangular. No jugal angle was developed because the shell-plates in transverse section are curved. Tegmental areas are not developed and the sculpture consists of small rounded pustules, equal in size over the whole tegmental surface.

The values of m and b of the holotype are 4.3 and 3.5 mm. respectively and, it is supposed, that $n = 0.5$ mm. From this it follows that

$$L = 4.3(8-2+\sqrt{2}) - 0.5(8-2) = 28.88 \text{ mm.}$$

and

$$Q = \frac{28.88}{3.5} = 8.25.$$

The shell of the specimen also was about 28 mm. in length and about 8 times as long as broad. This species as well as *Preacanthochiton cooperi* had a very thin body shape.

PREACANTHOCHITON PRODUCTUS, n. sp.
Text-fig. 1—7,8

Diagnosis: Sides of the posterior terminal valve almost straight and making a jugal angle varying between 60° and 90°.

Localities in Missouri and material.—455v[1], 1 unbroken and 2 fragments of posterior terminal valves. 261n[1], 2 posterior terminal valves.

Geological age.—Upper Cambrian.

Type.—Holotype, the figured terminal valve, USNM 137373.

Description.—On the basis of the listed material it is impossible to get a definite understanding about the shape of the body valves. It is probable that the jugal angle of body valves has the same value as that of the posterior terminal valve and that the covering was total. The shape of the posterior terminal valve is suggestive of that of the corresponding valves of *Preacanthochiton cooperi*, the mucro being extended to a cornet-like process similar to that of some specimens of *Preacanthochiton cooperi*. For this reason I put the species into genus *Preacanthochiton*.

The tegmentum is dissolved, therefore the sculpture cannot be described. As no body valve was found, a reconstruction of the shell is impossible and a calculation of the shell length yields an uncertain result. Supposing, however, the anterior terminal valve and each of the body valves were equal in length to the posterior terminal valve and that the inclination of the anterior terminal valve was about 45°, the length of the whole shell can be estimated to about 88 mm. While the value of b is about 8 mm., Q becomes 11. In spite of the very approximate characters of these numbers it is quite sure that the body shape of this species was long and narrow. A fossil loricate is known, however, i.e. *Septemchiton vermiformis* Bergenhayn, the Q of which is 17. This species is the longest and narrowest loricate yet described.

PREACANTHOCHITON n. sp. aff.
P. COOPERI, n. sp.
Text-fig. 1—9,10

Diagnosis: Sculpture consisting of small rounded pustules. Posterior terminal valve about twice as long as broad. Mucro very much elevated.

Localities and material.—261n[1], northeast; 1 cast of the inside of a posterior terminal valve; 261o, south. 1 posterior terminal valve; 100i, 1 posterior terminal valve; 399c, south. 1 posterior terminal valve.

Geological age.—All Upper Cambrian.

Type.—Figured specimen, terminal valve, USNM 137374.

Description: As appears from the list of the material only 3 posterior terminal valves and two casts of the inside of one posterior terminal valve have been examined. Owing to the fact that no body valve was found our knowledge of the species is rather meager. My opinion of the systematic position of the species depends upon its similarity in sculpture and shape of the posterior terminal valve to those of *Preacanthochiton cooperi.* The posterior terminal valve, however, is more narrowly elongate and arched in transverse section because the mucro is extended posteriorly to a process equal in length to half the valve length. A similar process is suggested in *Preacanthochiton cooperi* and *Preacanthochiton productus* but in these species not so extremely developed as in the species in question. This long mucro was hollow like that of *Preacanthochiton cooperi* and *Chelodes intermedius*, n. sp., (cf. page 173) and probably contained a muscle for attaching the posterior terminal valve. Concerning the shape of the shell and body this species in all probability was more elongate than *Preacanthochiton cooperi* and *Preacanthochiton depressus.* Because no body valve occurs a reconstruction of the shell and estimation of its length is not possible.

Family CHELODIDAE
Genus CHELODES Davidson and King
CHELODES INTERMEDIUS, n. sp.
Text-fig. 1—11–14

Diagnosis.—Body valves wedge- or heart-shaped. Anterior margin of body valves with one jugal lobe and one saddle on each side of lobe. Area apicalis of equal length or a little longer than half the length of the body valves. Mucro very strongly extended posteriorly.

Locality and material.—416c, 3 body valves and 4 posterior terminal valves.

Geological age.—Lower Ordovician (Chepultepec).

Type.—Holotype, the figured body valve, USNM 137375

Description.—The shape of the body valve is approximatively triangular or broadly heart-shaped. As in *Chelodes gotlandicus* Lindström (Bergenhayn, 1943, 1955) the anterior margin of the body valves and the posterior terminal valve are formed of one lobe and two saddles, but as in *Chelodes bergmanni* Davidson and King, the area apicalis is as long as or slightly longer than half the length of the median line.

Of the 4 posterior terminal valves 3 differ very strongly in shape from all posterior terminal valves hitherto known. The mucro is hollow and very strongly extended backwards, and this process of extension has even reached the jugal and posterior part, making the valves cornet-like. Another consequence of this development is that the posterior part of the valve makes an angle of 50° or 60° with the jugal part. These valves are also strongly compressed laterally and therefore narrower than the other valves in dorsal view. At the fourth terminal valve the mucro is strongly elevated and makes an angle of 90° with the ventral margin of the valve. Also at this valve the mucro is hollow (cf. page 175) and in this case too, I suppose that the cavity enclosed an anchoring muscle of the posterior terminal valve.

No anterior terminal valve is known, but probably these valves had about the same shape as that of *Chelodes gotlandicus* Lindström, and *Chelodes bergmanni* Davidson and King which, up to now, were the best known species of the genus.

The tegmentum is dissolved, and therefore the sculpture cannot be stated. Owing to the shape of the body valves (cf. Bergenhayn 1955, p. 9–10) the zones of growth are of the same breadth on all parts of the tegmental surface.

I have tried to estimate the approximate length of the whole shell from the holotype. For this estimate the formula before derived cannot be used because the mucro instead of the posterior margin of the posterior terminal valve makes the end of the shell. For this estimate the following formula was derived:

$$L=\frac{(m-n)(\sqrt{2}+14)}{2}.$$

In this formula L, m, and n have the same meaning as in the other formula. For the holotype $m=17$ mm., $n=8$ mm. and $b=17$ mm.

$$\therefore L=\frac{(17-8)(\sqrt{2}+14)}{2}\text{ mm.}=69.36\text{ mm.};$$

$$Q=\frac{69.36}{17}=4.08.$$

The animal was about 69 mm. in length and about 4 times as long as broad. Accordingly the circumference of the shell is elongate-oval (Von Middendorf, 1848; Bergenhayn, 1930a). The relative height of the holotype is estimated to be 0.76. Consequently the shell was of medium height (Bergenhayn 1930a).

This species resembles *Chelodes gotlandicus* Lindström in that the anterior margin of the body valves and the posterior terminal valve are developed with a median lobe and two lateral saddles. It resembles *Chelodes bergmanni* Davidson and King in having the area apicalis of the same length as or slightly longer than half the length of the body valves. The tegmental zones of growth are equal in breadth on all parts of the valves as on *Chelodes variegatus* Bergenhayn. It differs from the last mentioned species in that the body valves are not compressed laterally. With regard to the value of *Q* and especially the peculiar shape of the posterior terminal valve, the species diverges from other *Chelodes* species hitherto known. The author is tempted to consider the *Chelodes intermedius* as a collective form for the genus *Chelodes*. The name *intermedius* alludes to the fact that the species shows similarities to most other *Chelodes* species.

Chelodes depressus, n. sp.
Text-fig. 1—15,16

Diagnosis.—Circumference of body valves having approximately the form of a half ellipse. Anterior margin of body valves and posterior terminal valve with a shallow jugal lobe and two saddles. Area apicalis shorter than half the length of the median line of the body valves.

Localities and material.—438t, one strongly weathered body valve and one well preserved posterior terminal valve; 2464-co, Virginia. 3 body valves.

Geological age.—Lower Ordovician (Gasconade and Longview).

Type.—Holotype, the figured posterior terminal valve, USNM 137376.

Description.—The four body valves are badly weathered. Two of them are broken at the middle, one of them has lost its left anterior edge and one is quite destroyed by inexpert excavation from the matrix. The posterior terminal valve is well preserved. In spite of the bad state of the body valves, their shape can be stated with certainty.

Their circumference had approximately the same form as *Chelodes gotlandicus* Lindström and as in that species the area apicalis is shorter than half the length of the valves. The species resembles *Chelodes variegatus* Bergenhayn in that the shell is slightly compressed laterally but differs from the last mentioned species in being quite destitute of tegmental areas.

Owing to the bad state of preservation of the body valves, I have not been able to decide the values of *m*, *n* and *b* and therefore no reconstruction of the species has been made.

Chelodes ? sp. indet.
Text-fig. 1—17,18

Locality and material.—438t, one posterior terminal valve and 1 impression of another posterior terminal valve.

Geological age.—Lower Ordovician.

Type.—Figured specimen, posterior terminal valve, USNM 137378.

Description.—These fossils do not allow certain systematic determination. Nevertheless it seems possible to me that they represent a new species of the genus *Chelodes* Davidson and King.

Priscochiton ? sp. indet.
Text-fig. 1—19,20

Locality and material.—479a, one posterior terminal valve.

Geological age.— Upper Cambrian.

Type.—Figured specimens, posterior terminal valve, USNM 137377.

Description.—The valve is 7 mm. in length and 4 mm. broad. Its lateral slopes are weakly concave and make a jugal angle of 120°. The mucro is situated far back and the posterior part of the valve is weakly concave.

According to an enclosed label this fossil represents the genus *Priscochiton* Billings. As I am not acquainted with the type of that genus I cannot decide if this fossil belongs to *Priscochiton* or to some other genus.

GENERAL REMARKS ON PALEOZOOIC LORICATES

In an earlier paper (Bergenhayn, 1930a, 1930b, 1955) the author as well as Thiele (1893) and von Knorre (1925) proved that the shell of the recent loricates consists of the following superimposed layers: *periostracum*, which consists of organic substances only; tegmentum, which in its principal parts consists of a lot of organic substances but also of important lots of inorganic salts; *articulamentum s.s.*, which in most valves consists of several separate components. During the phylogenesis of the loricates this layer has been the object of a far-reaching development. The author (1930b) has proved that in certain highly organized recent loricates there is between the tegmentum and the articulamentum s.s., a shell-layer termed *mesostracum*. The lowermost shell-layer is the *hypostracum*.

H. von Knorre (1925) and the author (1930b, 1943 and 1955) have stated that the Paleozoic loricates up to the Carboniferous were quite destitute of articulamentum s.s. For the loricates destitute of articulamentum s.s., the author (1955) has proposed the subclass *Paleoloricata*, and for those having articulamentum s.s. another subclass *Neoloricata*. The lack of articulamentum s.s. was a very conservative character, existing from Cambrian to Senonian. Correlated with the absence of the articulamentum s.s., the shell muscles and shell-secreting epithelium were also at a lower stage of development.

In my paper (1955) I have asserted that the order *Chelodina* includes two evolutionary lines: (1) the genus *Chelodes* Davidson and King, the other (2) the genera *Gotlandochiton* Bergenhayn, *Haeggochiton* Bergenhayn, *Ivoechiton* Bergenhayn, *Scanochiton* Bergenhayn and *Olingechiton* Bergenhayn. Having established, however, that the genus *Preacanthochiton* belongs to the order *Chelodina*, this genus indubitably represents a third evolutionary line of the order. The evolutionary line 1 has not given origin to any neoloricate form; the evolutionary line 2 has given origin to all neoloricates except the orders *Acanthochitonina* and *Afossochitonina*. The last named orders must be derived from the preacanthochitonid line of evolution.

The most significant process phylogenetically in the evolution of the *Neoloricates* from paleoloricate ancestors was the beginning of the articulamentum s.s. This shell layer of the lepidopleuroid type (Bergenhayn, 1930b) did not arise until Devonian time. The first forms provided with this type of shell component belong, as far as I am aware, to the genera *Lepidopleurus* Risso and *Helminthochiton* Salter. It is unknown whether or not more advanced forms of articulamentum s.s. arose during the Paleozoic.

Rather characteristic of many paleozoic loricates, not only belonging to *Paleoloricata* but even to *Neoloricata* is their frequently narrow body. Another characteristic feature of the older paleozoic loricates is the complete or almost complete absence of tegmental areas and conspicuous sculpture. There is also reason for supposing that the color of the tegmentum was gray or olive-ashen.

Some older paleozoic loricates were bigger than most of the recent species. These bigger forms, however, no doubt had a very primitive anatomy and therefore Plate's (Plate, 1902) hypothesis that increasing body size gives rise to a higher anatomical organization has no general validity. On the other hand a probable correlation exists between the organization of the internal anatomy and the structure of the shell, especially the macroscropic and microscropic structure of the articulamentum s.s.

One of the older paleozoic genera, *Chelodes* Davidson and King, has a very wide geographic range. Barrande (1867) described some *Chelodes* valves from Gotlandian strata in Bohemia (cf. Bergenhayn 1955) and Lindström (1884) discovered *Chelodes* valves in Gotlandian strata on the Isle of Gotland. Further the author (1955) described a typical *Chelodes* species from middle Bala in Scotland, and in this paper *Chelodes* species from Missouri in the United States. As the geologically oldest *Chelodes* forms appear in North America, one might suppose that *Chelodes* originated in that part of the world and from there was spread to Europe, probably during Ordovician time. As the loricates, however, are sun, soil, water animals with a short freely swimming larval stage, they require very favorable geographical circumstances to be spread over the Atlantic Ocean.

This brief discussion about the geograph-

ical distribution of the genus *Chelodes* naturally rests on the hypothesis that its origin was monophyletic. Considering known facts, one nevertheless can deny that the origin of the genus could have been diphyletic. Judging from the examined material, the valves of the European forms with regard to the common shape are more homogeneous than those of the American forms. In this connection it may be pointed out that the author (1931) asserted the opinion that the genus *Choneplax* Dall probably originated diphyletically, partly in West Indian waters and partly in the western portion of the Indian Ocean.

The problem whether the origin of the genus *Chelodes* is monophyletic or polyphyletic can be solved only by further examination of a large collection of fossil material.

PRELIMINARY SYNOPTICAL TABLE OF THE SYSTEM OF THE LORICATES

Class LORICATA

Subclass PALEOLORICATA

Order SEPTEMCHITONINA
- Family SEPTEMCHITONIDAE
  - †*Septemchiton* Bergenhayn

Order CHELODINA
- Family CHELODIDAE
  - †*Chelodes* Davidson and King
- Family GOTLANDOCHITONIDAE
  - †*Gotlandochiton* Bergenhayn
- Family SCANOCHITONIDAE
  - †*Scanochiton* Bergenhayn
  - †*Olingechiton* Bergenhayn
  - †*Haeggochiton* Bergenhayn
  - †*Ivoechiton* Bergenhayn
- Family PREACANTHOCHITONIDAE
  - †*Preacanthochiton* Bergenhayn, n. gen.

Subclass NEOLORICATA

Order LEPIDOPLEURINA
- Family LEPIDOPLEURIDAE
  - *Lepidopleurus* Risso
  - *Oldrydia* Dall
  - †*Protochiton* Ashby
  - †*Helminthochiton* Salter
  - Genus *Pterochiton* Dall
  - Genus *Cymatochiton* Dall
  - Genus *Priscochiton* Billings
- Family HANLEYIDAE
  - Genus *Hanleya* Gray
  - Genus *Hemiarthrum* Dall
- Family CHORIPLAXIDAE
  - Genus *Choriplax* Pilsbry

Order ISCHNOCHITONINA
- Family SUBTERENOCHITONIDAE
  - Genus *Subterenochiton* Iredale and Hull
- Family ISCHNOCHITONIDAE
  - Genus *Ischnochiton* Gray
  - Genus *Trachydermon* Carpenter
  - Genus *Chondropleura* Thiele
  - Genus *Tonicina* Thiele
  - Genus *Lepidozona* Pilsbry
- Family SCHIZOPLAXIDAE
  - Genus *Schizoplax* Dall
- Family CALLOCHITONIDAE
  - Genus *Callochiton* Gray
  - Genus *Eudoxochiton* Shuttleworth
- Family CALLISTOPLACIDAE
  - Genus *Callistochiton* Dall
  - Genus *Nuttallochiton* Plate
  - Genus *Nuttallina* Dall
  - Genus *Notochiton* Thiele
  - Genus *Middendorfia* Dall
- Family CHAETOPLEURIDAE
  - Genus *Chaetopleura* Shuttleworth
  - Genus *Dinoplax* Dall
  - Genus *Calloplax* Thiele
- Family MOPALIDAE
  - Genus *Ceratozona* Dall
  - Genus *Mopalia* Gray
  - Genus *Placiphorella* Dall
  - Genus *Plaxiphora* Gray
  - Genus *Frembleya* H. Adams
  - Genus *Katharina* Gray
  - Genus *Amicula* Gray
- Family SCHIZOCHITONIDAE
  - Genus *Schizochiton* Gray
  - Genus *Lorica* Adams
- Family CHITONIDAE
  - Subfamily CHITONINAE
    - Genus *Chiton* Linné
    - Genus *Sclerochiton* Dall
  - Subfamily TONICINAE
    - Genus *Tonicia* Gray
    - Genus *Onithochiton* Gray
  - Subfamily ACANTHOPLEURINAE
    - Genus *Acanthopleura* Guilding
    - Genus *Liolophura* Pilsbry
    - Genus *Enoplochiton* Gray

Order ACANTHOCHITONINA
- Family ACANTHOCHITONIDAE
  - Subfamily ACANTHOCHITONINAE
    - Genus *Acanthochites* Risso
    - Genus *Choneplax* Dall
    - Genus *Aristochiton* Thiele
    - Genus *Craspedochiton* Shuttleworth
    - Genus *Spongiochiton* Dall
    - Genus *Cryptoconchus* Guilding
    - Genus *Cryptochiton* Gray
  - Subfamily CRYPTOPLACINAE
    - Genus *Austrochiton* Bergenhayn
    - Genus *Cryptoplax* de Blainville

Order AFOSSOCHITONA
- Family AFOSSOCHITONIDAE
  - Genus *Afossochiton* Ashby
- Family LLANDEILOCHITONIDAE
  - Genus *Llandeilochiton* Bergenhayn

† In front of the name of a genus means that the genus is extinct.

Concerning the family Llandeilochitonidae I cannot now decide, owing to the scanty material, one very peculiar body valve only (cf. Bergenhayn 1955), if the family belongs to one of the orders proposed before, or if it may be regarded as a member of some hitherto unknown group of lori-

cates. In connection with unpublished teratological investigations, "Die Teratologie der Loricatenschale," I have wondered whether this curious body valve represents a normal or an exceptional specimen.

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RUGOSE CORALS FROM THE LOWER MISSISSIPPIAN JOANA LIMESTONE OF NEVADA

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ABSTRACT—*Kakwiphyllum dux* Sutherland and *Lithostrotionella jasperensis* Kelly are described from the Lower Mississippian Joana limestone at Ward Mountain, White Pine County, Nevada and from other localities in east-central Nevada. Their presence suggests biostratigraphic correlation between the Joana limestone and parts of the Banff and Rundle formations of Western Canada.

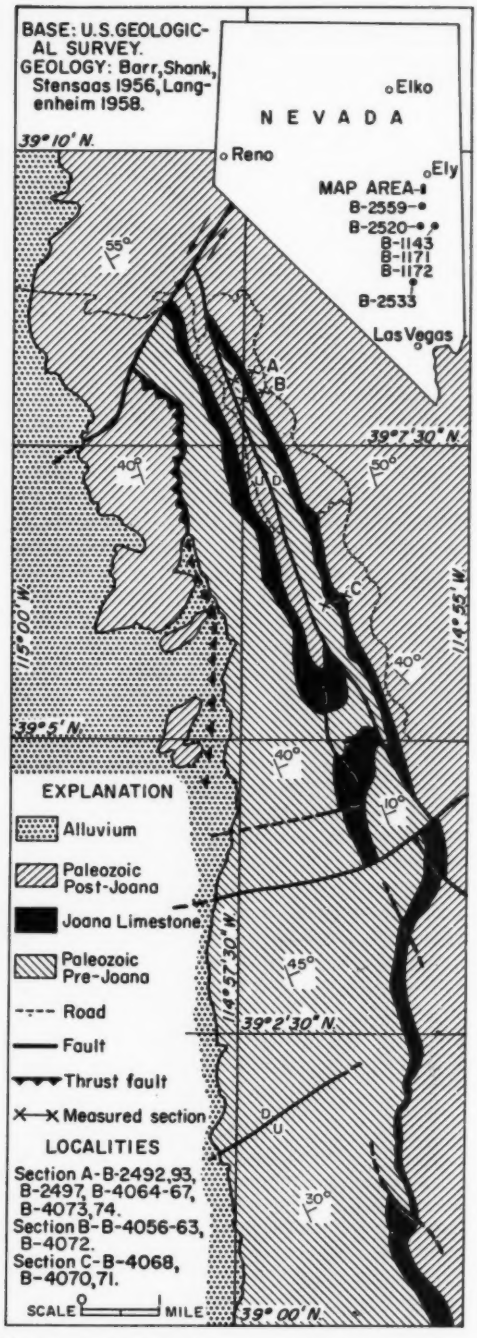
INTRODUCTION

Kakwiphyllum dux Sutherland and *Lithostrotionella jasperensis* Kelly associated with characteristic "Madison limestone" fossils are widespread in the Joana limestone of east-central Nevada (Text-fig. 1). Their occurrence here seems worthy of note because these fossils establish a biostratigraphic correlation between Mississippian deposits of the Great Basin and those of the Canadian Rockies. Also *Kakwiphyllum* is readily recognizable and generally retains its identifying characters in altered rock, thus furnishing a useful means of recognizing isolated, partially metamorphosed or badly deformed bodies of Joana limestone.

The Joana limestone of eastern Nevada includes three prominent members (Langenheim, 1956). The basal member is composed of massive, cliff-forming, cherty, crinoidal limestone and is most widespread. This unit is present wherever the Joana limestone is recognized and extends at least from Eureka, Nevada on the west to the Confusion Range of Utah on the east and from the Pequop Range of Nevada on the north to the Alamo, Nevada area to the south. Above the relatively unfossiliferous basal member a bench-forming sequence of thin to thick-bedded limestone is relatively chert-free but includes nodular shaly units. Fossils are abundant and widespread and *Kakwiphyllum* appears confined to this member and the succeeding cliff-forming member. With the exception of a single specimen from the lower member at Dutch John Mountain, *Lithostrotionella* spp. also appear limited to the middle or upper member. An upper cliff-forming member composed largely of thick-bedded limestone is well-developed only in the Pioche Basin between Alamo, Nevada and a point just south of Ward Mountain. Text-figure 2 is a composite section of the Joana limestone at Ward Mountain based on traverses approximately ¼ mile apart in sec. 26, T. 15 N., R. 62 E. as shown on the Ely 30′ Quadrangle Map, Edition of 1952. This figure shows the general character of the two lower members. The Ward Mountain locality is also the best available reference section for the Joana limestone inasmuch as the type area in the Robinson Mining District near Ely, Nevada includes only badly deformed, partially metamorphosed outcrops of the Joana limestone. These rocks are largely unfossiliferous and original sedimentary features are mostly destroyed. Furthermore, erosion has removed all but a small part of the middle member of the Joana limestone in the Robinson Mining District.

Kakwiphyllum dux and *Lithostrotionella jasperensis* are associated with many species of brachiopods and other invertebrates in the middle, bench-forming member of the Joana limestone at Ward Mountain. The following organisms have been identified from the indicated collecting localities:

Syringopora sp.—B-2492, B-4059
Fenestrellina sp.—B-4059, B-4062, B-4066
Trepostomatous bryozoa—B-4060, B-4061
Ambocoelia sp.—B-4059
Brachythyris sp.—B-4069
Camerophorella (?) sp.—B-4068
Camerotoechia metallica (White)—B-4059, B-4066, B-4071
Chonetes cf. *C. illinoisensis* Worthen—B-2493, B-4066, B-4070
Chontes logani Norwood and Pratten—B-2493, B-4059, B-4062, B-4066, B-4070
Cleiothyridina cf. *C. obomaxima* (McChesney)—B-2492, B-4069, B-4074
Cleiothyridina (?) sp. B—4059



TEXT-FIG. *1*—Location map of east-central Nevada showing collecting localities and geologic location map of Ward Mountain showing distribution of Joana limestone.

Composita cf. *C. lewisensis* Weller—B-4059, B-4074
Dielasma cf. *D. burlingtonensis* (White)—B-4059
Dielasma sp.—B-4059
Dictyoclostus burlingtonensis (Hall)—B-4062
Dictyoclostus fernglenensis (Weller)—B-4062, B-4072, B-4073, B-4074
Echinoconchus geneviviensis Weller—B-2492, B-4059, B-4062
Eumetria cf. *E. verneuiliana* (Hall)—B-4073
Eumetria sp.—B-4068
Leptaena analoga (Phillips)—B-2492, B-4073, B-4074
Linoproductus cf. *L. ovatus* (Hall)—B-4066, B-4073
Linoproductus cf. *L. tenuicostus* (Hall)—B-4062, B-4066
Productina sampsoni (Weller)—B-4062, B-4066, B-4072, B-4073
Schizophoria cf. *S. chouteauensis* Weller—B-4059, B-4074
Schizophoria cf. *S. sedaliensis* Weller—B-4066, B-4073, B-4074
Schuchertella desideratus (Hall and Clarke)—B-2492, B-2493, B-4059, B-4062, B-4073
Selenella (?) sp.—B-4056
Spirifer centronatus Winchell (of White)—B-2492, B-2497, B-4058, B-4059, B-4062, B-4066, B-4068, B-4069, B-4071, B-4072, B-4073, B-4074
Spirifer cf. *S. latior* Swallow—B-4059, B-4071, B-4073
Spirifer cf. *S. maplensis* Weller—B-2497
Spiriferina cf. *S. solidirostris* White—B-4062, B-4071
Spirifer sp.—B-4066, B-4059, B-4073
Syringothyris cf. *S. hannibalensis* (Swallow)—B-2492, B-4066, B-4074
Syringothyris cf. *S. subcuspidatus* (Hall)—B-4060, B-4066
Syringothyris sp.—B-4061
Euomphalus ophirensis (Hall and Whitfield)—B-2492, B-4059, B-4074
Euomphalus utahensis (Hall and Whitfield)—B-4059, B-4074
Naticopsis sp.—B-4074
Platyceras sp.—B-4059, B-4074
Phillipsia peroccidens (Hall and Whitfield)—B-2492, B-2493, B-2497, B-4074

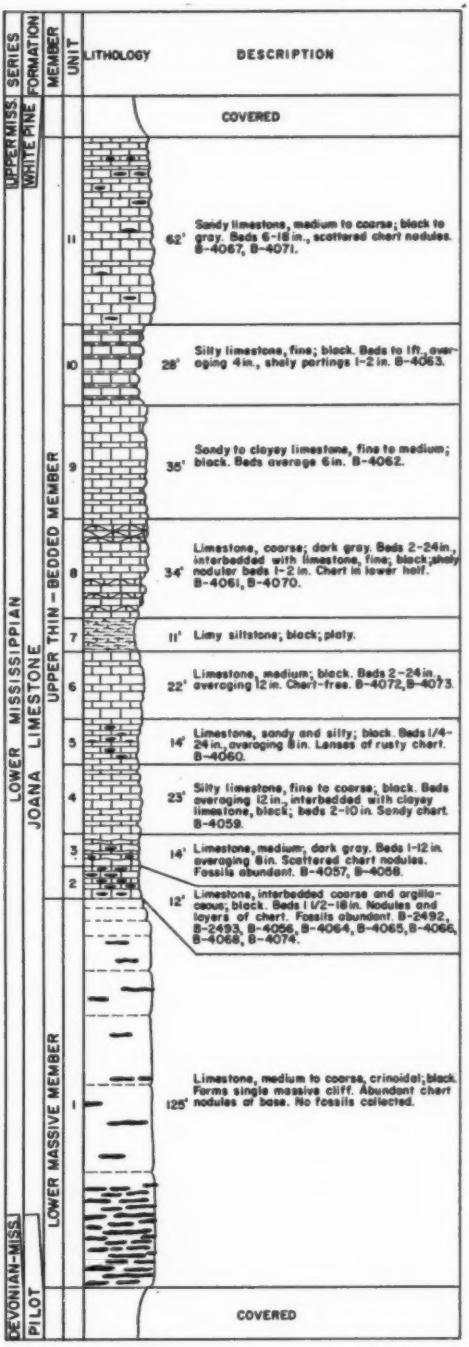
The specimens here described were collected by the junior author at various localities in east-central Nevada during the 1954, 1955, and 1958 field seasons and by the senior author in the Ward Mountain area (Text-fig. 1) during the 1956 field season. The composite columnar section (Text-fig. 2) is based on two sections, one measured by each author. Geologic mapping in the Ward Mountain area is the work of the senior author (Stensaas, 1957), Barr (1957), Shank (1957) and the junior author. Systematic descriptions are by the senior author but have been revised by the junior author who also prepared the remainder of the manu-

script. P. K. Sutherland reviewed the manuscript and offered many valuable suggestions. The authors, however, assume full responsibility for the form and content of the paper. Virginia McCutcheon prepared line drawings of the corals by bleaching inked photographs, and the maps and columnar sections are by Owen Poe. Field expenses in conjunction with this report were partially supplied through student aid funds of the Department of Paleontology of the University of California at Berkeley. The Gulf Oil Corporation kindly supplied aerial photographs for use in geologic mapping in the area. This paper is a contribution from the Museum of Paleontology of the University of California.

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA
Class ANTHOZOA
Subclass ZOANTHARIA
Order RUGOSA
Suborder STREPTELASMATINA
Superfamily ZAPHRENTICAE
Family CYATHOPSIDAE Dybowski, 1873
Genus KAKWIPHYLLUM Sutherland, 1954

Discussion.—When originally described by Sutherland (1954, p. 365–366) *Kakwiphyllum* was tentatively assigned to the Caniniidae. This family has since been placed in synonymy with the Cyathopsidae by Hill (1956, p. 291) and this usage is followed in this paper. *Kakwiphyllum* does not, however possess an open tabular fossula, amplexoid septa in the tabularium or complete domed or flat tubulae, all of which are characteristic of the cyathopsids. In the general arrangement of septa and in the presence of lonsdaleoid dissepiments, *K. dux* somewhat resembles *Acanthophyllum* of the Ptenophyllidae and *Stringophyllum* of the Stringophyllidae. According to Sutherland, however (personal communication), "both the Devonian families just mentioned have a a septal structure characterized by the presence of well developed trabeculae, a feature lacking in *Kakwiphyllum* in which the septa have the fibre fasicles arranged at right angles to the plane of the septa. The family position of *Kakwiphyllum* has been discussed by correspondence with Dorothy Hill who agrees to the importance of the differences in septal structure just men-


SERIES
FORMATION
MEMBER
UNIT
LITHOLOGY
DESCRIPTION
UPPER MISSI
WHITE PINE
LOWER MISSISSIPPIAN
JOANA LIMESTONE
UPPER THIN-BEDDED MEMBER
LOWER MASSIVE MEMBER
DEVONIAN-MISS.
PILOT
COVERED
62' Sandy limestone, medium to coarse; black to gray. Beds 6-18 in., scattered chert nodules. B-4067, B-4071.
28' Silty limestone, fine; black. Beds to 1ft., averaging 4 in., shaly partings 1-2 in. B-4063.
35' Sandy to clayey limestone, fine to medium; black. Beds average 6 in. B-4062.
34' Limestone, coarse; dark gray. Beds 2-24 in., interbedded with limestone, fine; black; shaly nodular beds 1-2 in. Chert in lower half. B-4061, B-4070.
11' Limy siltstone; black; platy.
22' Limestone, medium; black. Beds 2-24 in., averaging 12 in. Chert-free. B-4072, B-4073.
14' Limestone, sandy and silty; black. Beds 1/4-24 in., averaging 8 in. Lenses of rusty chert. B-4060.
23' Silty limestone, fine to coarse; black. Beds averaging 12 in., interbedded with clayey limestone, black; beds 2-10 in. Sandy chert. B-4059.
14' Limestone, medium; dark gray. Beds 1-12 in. averaging 8 in. Scattered chert nodules. Fossils abundant. B-4057, B-4058.
12' Limestone, interbedded coarse and argillaceous; black. Beds 1 1/2-18 in. Nodules and layers of chert. Fossils abundant. B-2492, B-2493, B-4056, B-4064, B-4065, B-4066, B-4068, B-4074.
125' Limestone, medium to coarse, crinoidal; black. Forms single massive cliff. Abundant chert nodules at base. No fossils collected.
COVERED
11
10
9
8
7
6
5
4
3
2
1

TEXT-FIG. 2—Columnar section of Joana limestone on Ward Mountain showing stratigraphic occurrence of invertebrate fossils.

tioned. The genus should be tentatively placed in the Cyathopsidae until its relations, particularly in reference to the unusual axial depression of the tabulae are better understood." The microstructure of the septa in specimens of *Kakwiphyllum* from the Joana limestone resembles that of specimens described by Sutherland (1954, p. 366–368, Pl. X, figs. 1a–c, text-figs. 2a,b; 1958, p. 69–70, Pl. XVIII, figs. 1a–d, Pl. XIX, figs. 1–3).

Kakwiphyllum is grossly similar to *Faberophyllum* as described by Parks (1951, p. 177) from Utah, but lacks a fossula, has fewer septa, and differs in the character of the dissepimental zone. *Kakwiphyllum* resembles *Caninophyllum incrassatum* Easton and Gutschick (1953, p. 17–19, Pl. III, figs. 1–4) from the Redwall limestone of Arizona in size and number of septa, but differs in having a wide lonsdaleoid dissepimentarium. The size and number of septa of *Triplophyllites californicus* Tischler are similar to that of *Kakwiphyllum*, but the fossula and the absence of a lonsdaleoid dissepimentarium are distinguishing features.

KAKWIPHYLLUM DUX Sutherland, 1954
Text-figs. 3–8

Kakwiphyllum dux Sutherland, 1954, p. 361–371, pl. 10, text-fig. 2, Sutherland, 1958, p. 70–71, pl. XIX, text-figs. 1a–d.

Externals.—Large, solitary, cylindrical corallites, when mature ranging in diameter from 3 cm. to 7 cm., and in length from 7 cm. to 28 cm. Epitheca characterized by rounded interseptal ridges. Large transverse wrinkles and constrictions caused by periods of rejuvenation produce a scolecoid configuration. Calyx composed of calycal platform, corresponding to area occupied by inner dissepimental zone, and calycal pit into which septa project for 2–3 mm.

Internals.—Ephebic stage characterized by development of 55–65 thin flexuous septa extending to center of calyx with isolated examples crossing calyx; septa generally thin but may be dilated in tabularium; septa have overall radial symmetry but generally grouped into four or five series by shortening and bunching. Two regions of shortening correspond to cardinal and counter septa, others disrupt bilateral symmetry about cardinal-counter line, but this character is not consistent within species. Cardinal and counter fossulae generally absent; minor septa irregularly developed in inner dissepimental zone characterized by herring-bone dissepiments. In ephebic stage dissepimentarium consists of two parts equalling approximately one-half radius of corallite: conspicuous outer zone of gently inclined lonsdaleoid dissepiments occupies over one-third radius; inner zone of steeply inclined dissepiments separates outer zone from tabularium. Tabulae are inclined downward toward axis at moderate angle and form concave floor in axial region.

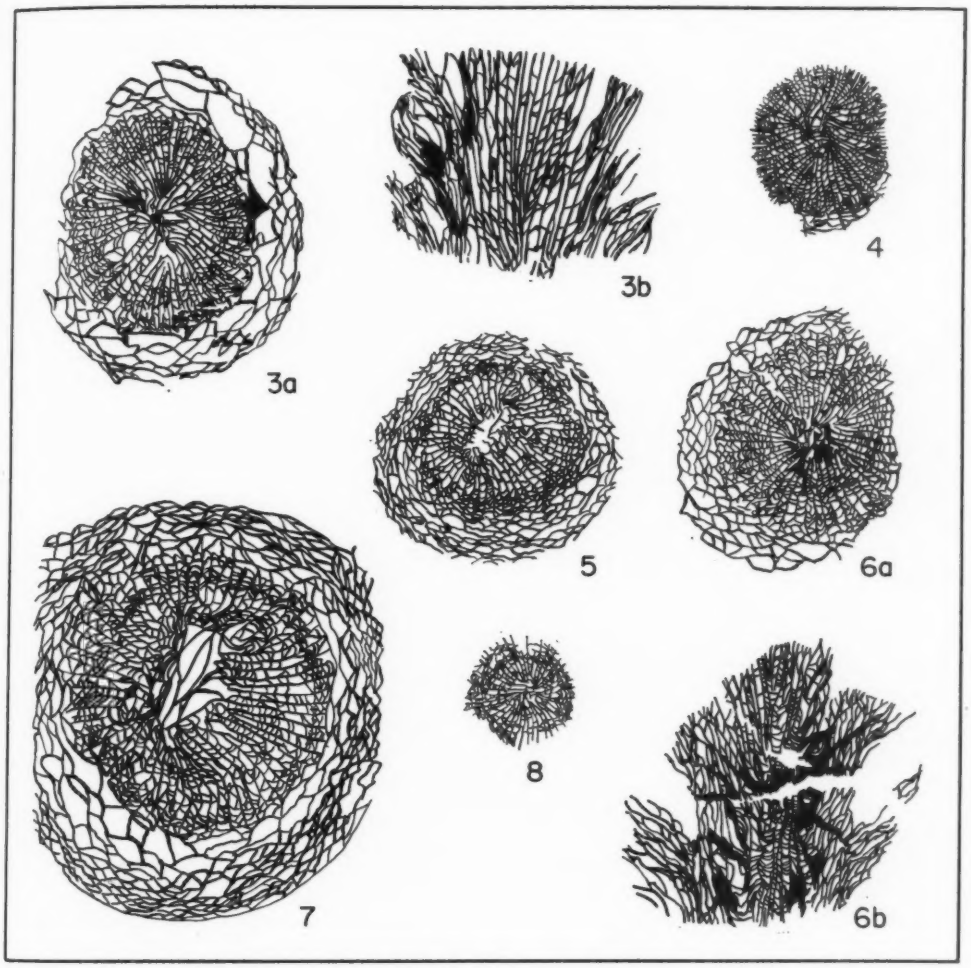
Neanic stage characterized by development of 40–55 septa extending to epitheca; no outer dissepimental area. Grouping of septa into series by areas of shortening and bunching well developed.

No specimens found with prototheca intact. Early development of dissepiments and relatively large number of septa in numerous small corallites indicate these specimens are immature individuals or broken apices of *K. dux*. Although mode of insertion of primary septa is not visible because of silicification, in one specimen approximately 5 mm. from tip, approximately 30 septa are present.

Documentation.—Hypotypes 30261 and 30262 are from locality B-4068, hypotype 30263 is from locality B-2497, hypotype 30264 is from locality B-2492, hypotype 30265 is from locality B-4067, and hypotype 30266 is from locality B-2492. All of the types are on file in the collections of the Museum of Paleontology, University of California, Berkeley. Approximately 95 specimens from collecting localities B-1143, B-1172, B-2492, B-2493, B-2497, B-2533, B-2559, B-4057, B-4060, B-4062, B-4064, B-4066, B-4067, B-4069, B-4071, B-4073, and B-4074 support this description.

Occurrence.—Middle and Upper Joana limestone at Dutch John Mountain (also referred to here as Bristol Pass limestone), Lincoln County, Nevada; Ward Mountain, White Pine County, Nevada; Alamo, Lincoln County, Nevada; and Cave Valley, White Pine County, Nevada.

Discussion.—Sutherland (1954, p. 365–368, Pl. X, figs. 1–2; 1958, p. 70–71, Pl. XIX, figs. 1a–d, 2) in addition to *Kakwiphyllum dux* also describes and figures



TEXT-FIGS. *3–8*—*Kakwiphyllum dux* Sutherland. All figures are inked and bleached photographs made using the thin-section as a negative. All figures are ×1. *3a*, transverse section in ephebic stage, UCMP 30266, Loc. 2492. *3b*, longitudinal section. *4*, transverse section in late neanic stage, UCMP 30265, Loc. B-4067. *5*, transverse section in ephebic stage, UCMP 30263, Loc. B-2497. *6a*, transverse section in ephebic stage, note radial symmetry, UCMP 30262, Loc. B-4068. *6b*, longitudinal section perpendicular to cardinal-counter plane, note small tabulae and two distinct dissepimental zones. *7*, transverse section in late ephebic stage, note wide outer dissepimental area, extreme size and radial symmetry, UCMP 30261, Loc. B-4068. *8*, transverse section in middle neanic stage, note absence of lonsdaleoid dissepiments, UCMP 30264, Loc. B-2492.

Kakwiphyllum cf. *K. dux* and *Kakwiphyllum* sp. A. These three taxa differ in number of septa with 66 in *K. dux*, 72 to 78 in *K.* cf. *K. dux*, and 84 in *K.* sp. A. *K. dux* and *K.* sp. A lack a cardinal fossula but *K.* cf. *K. dux* has a small cardinal fossula. *K. dux* has thin septa, *K.* sp. A has slightly thicker septa and *K.* cf. *K. dux* has septal thickening in the tabularium. In addition the pattern of septal bunching differs in the three taxa. Thus *Kakwiphyllum* as presently constituted includes one precisely defined species and two unevaluated slighlty varying taxonomic groups. These animals occcur in three widely spaced localities along the Canadian Rockies between Banff, Alberta and the

Liard River in southern Northwest Territory and they apparently range stratigraphically from the upper Banff formation through the upper Rundle formation.

In Nevada, *Kakwiphyllum* is presently known to occur only in a relatively thin stratigraphic sequence in the middle and upper Joana limestone. Specimens from this restricted interval, however, duplicate the variants described by Sutherland in the characters of septal thickening, septal bunching, and development of fossulae. None of our specimens, however, have more than 65 septa and thus differ in this respect from Sutherland's *K.* cf. *K. dux* and *K.* sp. A.

Inasmuch as all the Nevada specimens are from approximately the same stratigraphic position and are geographically distributed in a manner indicating a continuous range we have decided to treat them as belonging to a single species. They are referred to *Kakwiphyllum dux* because almost all have approximately the same number of septa as *K. dux* and the majority more closely resemble *K. dux* than *K.* cf. *K. dux* or *K.* sp. A in other characters. Description of a new species or several new species based on these materials does not appear warranted at this time because they display a wide but continuous range of morphologic character. Furthermore, naming a new species would obscure the stratigraphically and biologically significant similarities between the various Nevada collections and those from the Canadian Rockies.

Suborder COLUMNARIINA
Family LONSDALEIIDAE Chapman, 1893
Subfamily LONSDALEIINAE Chapman, 1893
Genus LITHOSTROTIONELLA Yabe and Hayasaka, 1915

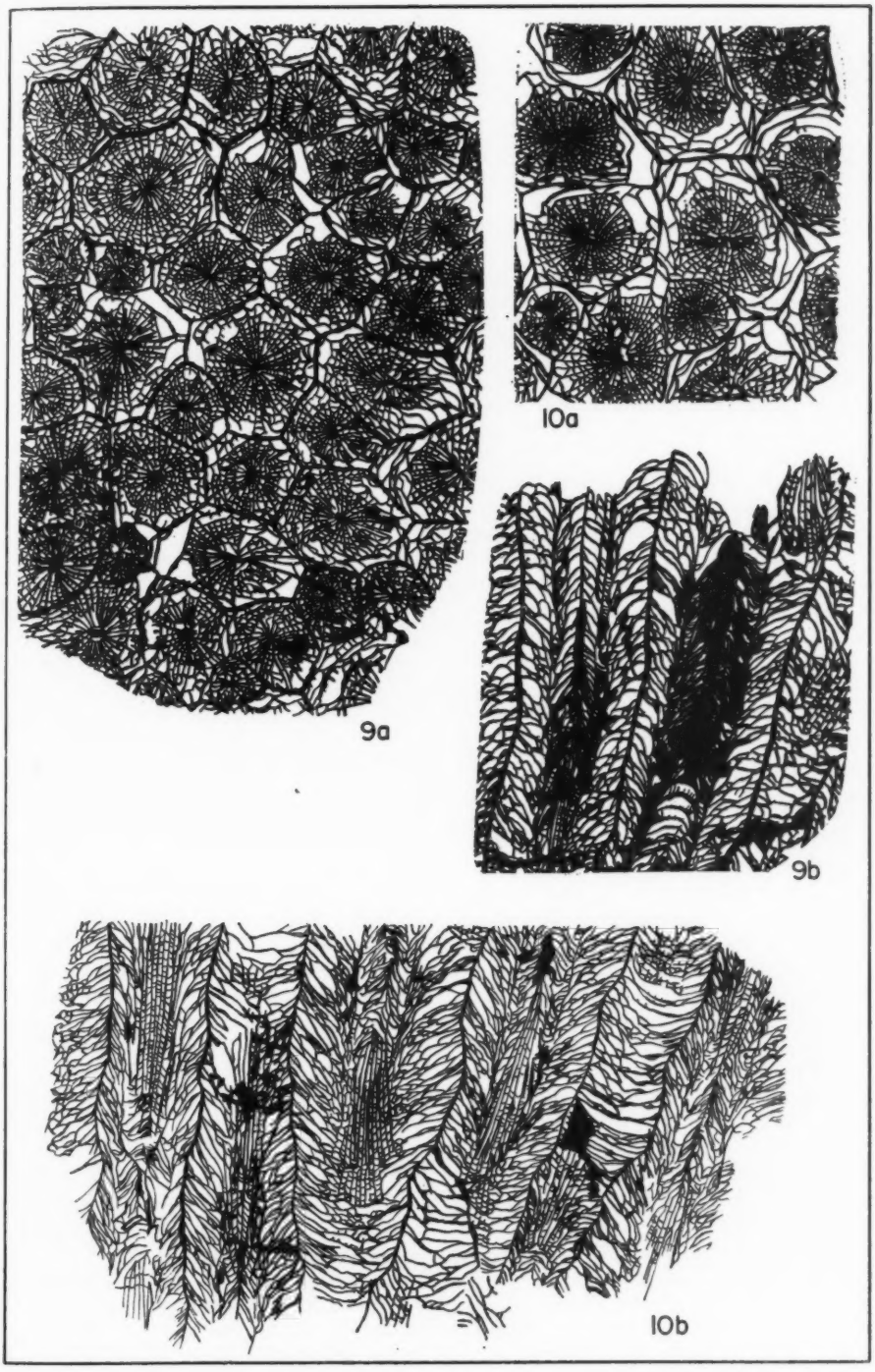
Discussion.—Major septa in *Lithostrotionella* from Ward Mountain generally extend to the epitheca only where the outer lonsdaleoid dissepimental zone is abnormally thin because of irregularities in the outer wall of the corallite. In some corallites, however, even though the dissepimentarium is of normal thickness, a very few major septa do reach the epitheca and in this way are similar to those of *Lithostrotion.* Likewise, some corallites resemble *Lonsdaleia* in possessing a compound axial column composed of irregularly developed tabullae, steeply inclined to the median plate. The occurrence of septa extending to the epitheca, and the development of a compound axial column in these corals from Ward Mountain are instances in which defining characters of more than one genus are present in corallites from a single corallum. Inasmuch as most of the corallites are of lithostrotionellid character these corals are placed in *Lithostrotionella* without further qualification.

LITHOSTROTIONELLA JASPERENSIS Kelly
Text-figs. 9,10

Lithostrotionella jasperensis, Kelly, 1942, p. 356-357, pl. 51, text-figs. 3,6.

External.—Corallum ranges from less than three inches in diameter to over five feet, irregularly mushroom-shaped; outer surface generally silicified. Corallites irregularly polygonal; slightly flexuous, from 4 to 15 mm. in diameter, averaging about 10 mm., calyx shallow, peripheral area sloping inward to a depth of about 1.5 mm. Central area more deeply impressed to form a calicular pit about 1 mm. deep and about one-third diameter of corallite in width. Bottom of cavity slightly concave with small slightly compressed columella piercing floor and rising nearly to top. Corallites abruptly increases in size and number from apex; holotheca not preserved.

Transverse sections.—Corallites cerioid and generally divided into three zones of which the outer two are within the dissepimentarium and poorly differentiated and the inner in within the tabularium. Outer zone characterized by lonsdaleoid dissepiments occupying about two-fifths the radius but is penetrated by a few irregularly spaced major septa or discontinuous septal ridges. Intermediate zone characterized by continuous major septa alternating with long minor septa spanning the full width of the zone. Minor septa generally about 3 mm. long. There are 20 to 22 (rarely 24) long major septa which converge slightly towards cardinal and counter septa. Dissepiments in the intermediate zone are small and relatively closely spaced. Central zone tabulate and generally distinct. Major septa cross tabularium to touch the columella. Columella moderately thick, spindle-shaped, and elongated in the counter-cardinal plane.



TEXT-FIGS. *9,10—Lithostrotionella jasperensis* Kelly. All figures are inked and bleached photographs made using thin-sections as the negatives. All figures are ×2. *9a*, transverse section of ephebic corallites, UCMP 30275, Loc. B-4066. *9b*, longitudinal section. *10a*, transverse section of neanic to ephebic corallites, note septa reaching outer wall in many mature corallites, UCMP 30274, Loc. B-2492. *10b*, longitudinal section.

Axial ends of minor septa penetrate tabularium slightly or not at all.

Longitudinal section.—Dissepimentarium distinctive; equal to two outer zones in transverse section. Outer dissepiments large (about 10 to 1 cm.), moderately convex and curving inward at a progressively greater angle. Outer dissepiments gradationally replaced by smaller, more globular, more steeply inclined dissepiments near the inner edge of the dissepimentarium. Tabulae characterize conspicuous inner zone, are generally complete, flat at periphery, arch gently upward toward axis, but tend to become flattened near columella. Narrow, flat zone at periphery also marked by numerous incomplete tabulae. Columella distinct and continuous.

Documentation.—Hypotype 30270 is from locality B-1171, hypotype 30271 is from locality B-1172, hypotype 30272 is from locality B-2559, hypotype 30273 is from locality B-2520, hypotype 30274 is from locality B-2492, and hypotype 30275 is from locality B-4066. All of the types are on file in the collections of the Museum of Paleontology, University of California, Berkeley. Approximately twenty specimens from collecting localities B-1171, B-1172, B-2492, B-2493, B-2520, B-2559, B-4057, B-4064, B-4066, B-4068, B-4073, and B-4074 support this description.

Occurrence.—Middle and Upper Joana limestone at Dutch John Mountain (also referred to here as Bristol Pass limestone), Lincoln County, Nevada; Ward Mountain, White Pine County, Nevada; Sunnyside, Lincoln County, Nevada; and Cave Valley, White Pine County, Nevada.

Discussion.—The specimens described here from Nevada closely resemble *Lithostrotionella jasperensis* Kelly from Canada (Kelly, 1942, p. 356) excepting minor variations such as the slightly smaller dissepiments arranged in more numerous rows. Kelly (1942, p. 356) points out that *L. jasperensis* differs from *L. banffensis* (Warren) by having relatively longer minor septa. Also the corallites of *L. banffensis* average 6 mm. in diameter (Warren, 1927, p. 46) instead of 10 to 12 mm. as in *L. jasperensis*. *L. jasperensis* also differs from *L. castelnaui* Hayasaka and *L. hemispherica* Hayasaka in its smaller size, fewer septa and flattened tabulae. Finally, our specimens have thicker, more rounded dissepiments occurring in fewer rows than is the case in *L. confluens* (Easton, 1958, p. 31–33, Pl. 1, fig. 12, Pl. 2, figs. 8,9).

CONCLUSIONS

In the Egan Range of Nevada, *Kakwiphyllum dux* and *Lithostrotionella jasperensis* are both essentially restricted to the upper two thirds of the Joana limestone. Both species were originally described from the Mississippian rocks of the Canadian Rockies where their reported cumulative range is from the upper Banff formation through the Rundle limestone (Kelly, 1942, p. 357, Sutherland, 1954, p. 366–368, 1958, p. 69). In addition, *L. jasperensis* is reported from the Brazer limestone at Hannah Gulch, Montana (Kelly, 1942, p. 357). On this basis the two corals may be considered roughly indicative of a middle Mississippian age, presumably late Osagian through Meremacian. Futhermore, neither species occurs in the newly described fauna near Bisani, Sonora, Mexico which Easton believes pre-Meremacian (Easton, 1958, p. 10–11). Easton also reports (Easton, Sanders, Knight and Miller, 1958, p. 11–12) elements of the Bisani fauna from the basal Monte Cristo limestone (Dawn and, possibly, Anchor members), the Joana limestone, the Bristol Pass limestone and the Rogers Spring limestone of Nevada; the Midridge limestone of Utah; and the Redwall limestone of Arizona. Two of these occurrences, Monte Cristo limestone and Rogers Spring limestone, are in rocks believed to be lithologically equivalent to the lower, cliff-forming members of the Joana limestone (Langenheim, 1956). It is also pertinent to note the absence of both *K. dux* and *L. jasperensis* in a fairly large fossil collection from the type section of the Bristol Pass limestone at Bristol Pass, Lincoln County, Nevada. This exposure includes only the lower cliff-forming member of the widespread Joana, or Bristol Pass, limestone. Thus it appears possible that there are at least two well-defined, widespread coral faunas in the Mississippian rocks of the Great Basin; one of approximate late Kinderhookian-Osagian age occurring in the lower cliff-forming member of the Joana limestone and its equivalents and one

of approximate late Osagian to Meremacian age which occurs in the middle and upper Joana limestone members and their equivalents.

CATALOGUE OF LOCALITIES

B-1143 Bristol Pass limestone, upper 150 feet, south slope of Dutch John Mountain about two miles east of the crest of the divide south of Dutch John Mountain. Approximate center Sec. 10, T. 6 N., R. 65 E., Lincoln County, Nevada as shown on Grazing Service, Range Surveys, Nevada Map No. 83, Edition of 1946.

B-1171 Bristol Pass limestone lower cliff-forming member, east side of Dutch John Mountain on the spur north of the third canyon north of the south end of the mountain. Approximately in the north ½ Sec. 3, T. 6 N., R. 65 E., Lincoln County, Nevada as shown on Grazing Service, Range Surveys, Nevada Map No. 83, Edition of 1946.

B-1172 Bristol Pass limestone general collection from middle bench-forming member and upper cliff-forming member at same general locality as B-1171.

B-2492 Joana limestone, 160 feet above base in the thin bedded member section located on the north slope of the water gap through the upper strike ridge formed by the Joana limestone approximately in the center of Sec. 26, T. 15 N., R. 62 E. as shown in the Ely 30′ Quadrangle Edition of 1952.

B-2493 Joana limestone. 265 feet above the base, in the thin bedded member. Same measured section as B-2492.

B-2497 Joana limestone, talus below cliff in vicinity of measured section containing localities B-2492 and B-2493.

B2520 Joana limestone, approximately 130 feet above base in the middle thin-bedded member in section measured on the west side of the strike valley in the White Pine shale approximately 1½ miles north of Trough Springs Canyon. Location is approximately in the NW ¼ Sec. 1, T. 6 N., R. 62 E., Lincoln County, Nevada.

B-2533 Joana limestone, general collection from uppermost 380 feet, in middle thin-bedded and upper cliff-forming members, approximately 4½ miles west of Highway maintenance station at Alamo, Lincoln County, Nevada. Section is located on crest of spur north of prominent canyon opening eastward from Pahranagat Range.

B-2559 Joana limestone, general collection, 285 to 530 feet above base, entirely within middle thin-bedded member, measured section located in Sec. 33, T. 10 N., R. 63 E., White Pine County, Nevada as shown on Grazing Service, Range Survey Maps, Edition of 1946.

B-4056 Joana limestone, Unit 2, base of middle thin-bedded member, black, cherty coarsely crystalline limestone above the contact with the lower member in a measured section located on the spur south of the water gap through the upper strike ridge formed by the Joana limestone and argillaceous limestone in the south ½ of Sec. 26, T. 15 N., R. 62 E. and approximately 700 feet south of the measured section of localities B-2492, B-2493 and B-2497.

B-4057 Joana limestone, Unit 3, the 14 foot interval of dark-gray, medium-grained limestone from 12 to 26 feet above the contact with the lower massive member. See B-4056, for locations of section traverse.

B-4058 Joana limestone, Unit 3, the 4 foot interval of dark-gray, medium-grained limestone from 17 to 21 feet above the contact with the lower massive member. See B-4056, for location of section traverse.

B-4059 Joana limestone, Unit 4, the 23 foot interval of black, silty to coarse-grained limestone from 26 to 49 feet above the contact with the lower massive member. See description of B-4056 for location of section traverse.

B-4060 Joana limestone, Unit 5, the 14 foot interval of black, silty to coarse-grained limestone with lenses and nodules of sandy chert from 49 to 63 feet above the contact with the lower massive member. See description of B-4056 for location of section traverse.

B-4061 Joana limestone, Unit 8, the 34 foot interval of dark-gray, uniformly coarse-grained limestone from 96 to 136 feet above the contact with the lower, massive member. See description of B-4056 for location of section traverse.

B-4062 Joana limestone, Unit 9, the 35 foot interval of black, thin-bedded, fine to medium-grained, sandy to argillaceous limestone from 136 to 171 feet above the contact with the lower massive member. See description of B-4056 for location of section traverse.

B-4063 Joana limestone, Unit 10, the 28 foot interval of black, fine-grained limestone with shaly partings from 171 to 199 feet above the contact with the lower massive member. See description of B-4056 for location of section traverse.

B-4064 Joana limestone, Unit 2, float sample, see B-4056 for description of unit. Section traverse same as that described for B-2492.

B-4065 Same as B-4064.

B-4066 Same as B-4064 but collected from rock in place.

B-4067 Joana limestone, Unit 11, the 62 foot interval of black, medium to coarse-

grained, sandy limestone with scattered thin chert nodules from 199 to 261 feet above the contact with the lower massive member. See description of B-2492 for location of section traverse.

B-4068 Joana limestone, Unit 2, see B-4056 for description of unit. Collected from hogback in SW ¼, Sec. 1, T. 14 N., R. 62 E., White Pine County, Nevada as shown on the Ely 30′ Quadrangle Ed. 1952.

B-4069 Joana limestone, West side of Ward Mountain, White Pine County, Nevada.

B-4070 Joana limestone, Unit 8, see B-4061 for description of unit. See B-4068 for general location.

B-4071 Joana limestone, Unit 11, see B-4067 for description of unit. See B-4068 for general location.

B-4072 Joana limestone, Unit 6, the 22 foot interval of black, medium-grained limestone from 63 to 85 feet above the contact with the lower massive member. See B-4056 for location of section traverse.

B-4073 Joana limestone, Unit 6, see B-4072 for description of unit. See B-2492 for location of section traverse.

B-4074 Joana limestone, Unit 2, see B-4056 for description of unit. Limestone immediately above the contact with the lower, massive member. See B-2492 for location of section traverse.

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EPIZOANS AS A KEY TO AMMONOID ECOLOGY

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ABSTRACT—The way in which epizoic oysters are attached to an adult shell of *Buchiceras* indicates that, (1) this shell was not covered by soft parts, (2) the adult stage of an ammonoid lasted probably for years, (3) *Buchiceras* did not crawl on the sea floor but swam in a position similar to that of living *Nautilus*.

THE epifauna of ammonoid shells has been used before to elucidate the ecology of the ammonoids. Examples of epifaunal pelecypods, brachiopods, bryozoans or annelids sealed between successive whorls of ammonites have been reported from different horizons and different species of goniatites, ceratites, and ammonites. Such occurrences, many of which have been listed by Schindewolf (1934, p. 15), prove that epizoans not only incrusted dead shells, but also could grow on *living* ammonoids. They further prove that the ammonoid shell could not have been covered by soft parts, as was recently suggested by Beurlen (1957), but lay exposed like the shell of the living *Nautilus*.

Among the epizoans, which encrusted living shells, certain Lower Jurassic serpulids did not grow at random, but preferred to follow the venter of the ammonite shell in the same sense and probably at the same rate as the ammonite grew. Using this evidence, Schindewolf estimated that it took the ammonite between one-half and three years to build its last whorl. He, as Lange before him, suggested that the spiral growth of the worm was controlled by its tendency to grow always towards the highest point of the ammonite. This would mean oriented growth in relation to the inclination of the subsurface. Slope orientation is a phenomenon often found among epifaunal organisms, particularly if growth direction is more constant and more independent of the sculpture of the subsurface than it is among serpulids, and if slope direction at a particular spot remains more constant than on a growing ammonite shell.

[1] The writer wishes to thank Professor K. E. Caster, University of Cincinnati and Professor K. O. Emery, University of Southern California for critical reading of the manuscript.

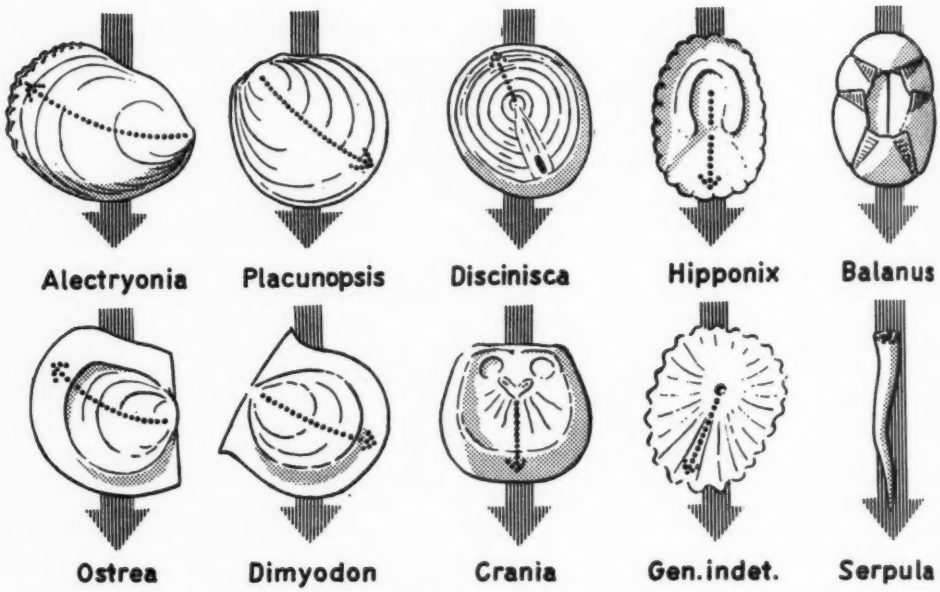
In an earlier paper (1954) the author suggested the use of oriented epizoans on the flanks of an ammonite shell to indicate the living ammonite's attitude. A specimen adequately illustrative of this was not known then, but one has now been found in the collection of the Department of Geology and Paleontology of Frankfurt University (Germany). Before passing, however, to the description and interpretation of this specimen, a few words should be said about slope orientation in general.

EPIZOANS AS SLOPE INDICATORS

Among the epizoans attached to steep or vertical surfaces, only few species are completely indifferent towards direction of slope. Most prefer a certain orientation which suits them best for gathering food and for other biological functions (text-fig. 1). They attain this attitude through either photo- or geotropism, which has been a question of minor concern to paleontologists.

Several factors may obscure slope orientation, particularly if the subsurface is but slightly inclined. On strongly sculptured surfaces, or in dense populations, thigmotaxis may prevail over the reaction to light or gravity. Rheotropism may under strong unidirectional currents have a similar effect (Barnes, 1953). Interferences of this kind are most common among serpulids and barnacles. Slope orientation seems to be a more dominant factor for epifaunal pelecypods and brachiopods, which usually can not adjust growth direction if the orientation of the host subsurface changes after the larva has become attached.

F. Schmid (1949) was first to treat slope orientation in the field of paleontology. The objects studied were small pelecypods, brachiopods and serpulids incrusting Cre-

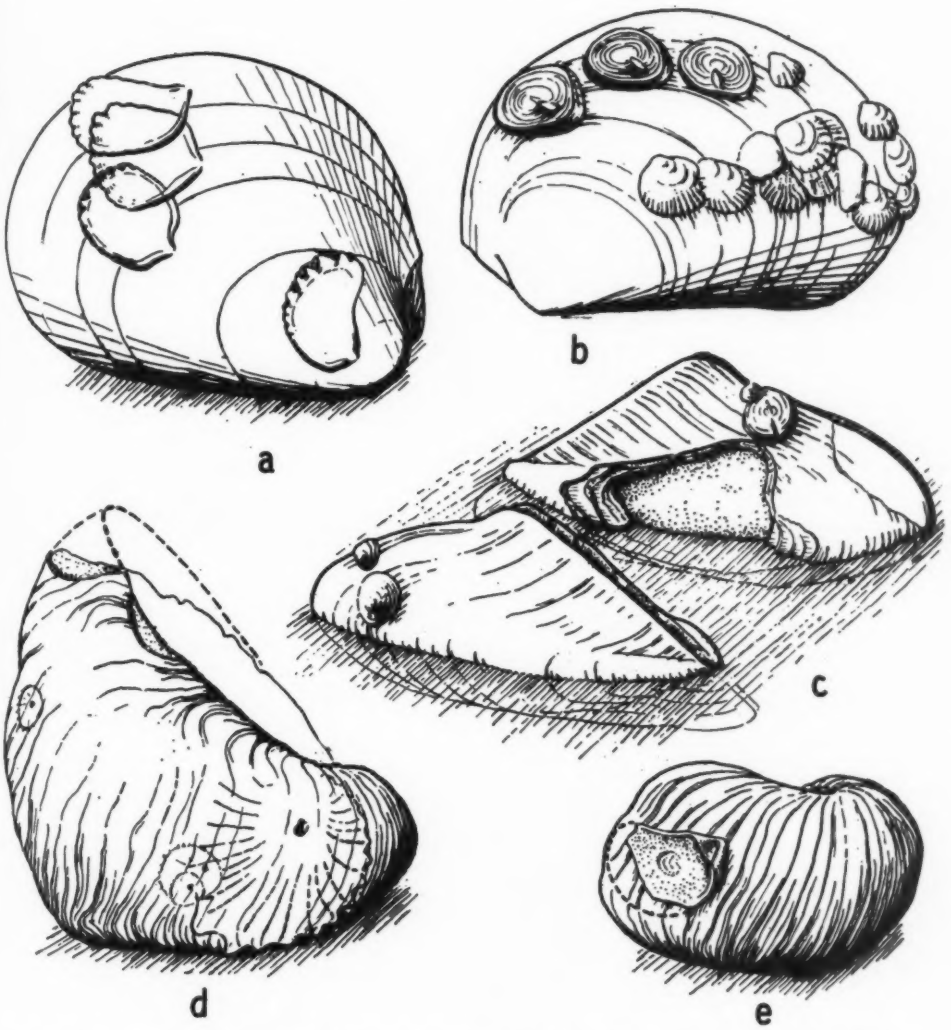


TEXT-FIG. *1—Preferential slope orientation of some epizoans*
Broken arrows = direction of growth
Lined arrows = direction of dip
True oysters (attached with their left valve):
Alectryonia, Middle Triassic
Ostrea, Upper Cretaceous
False oysters (attached with their right valves):
Placunopsis, Middle Triassic
Dimyodon, Upper Cretaceous
Inarticulate brachiopods:
Discinisca, Middle Triassic
Crania, Upper Cretaceous and Recent
Shallow impressions etched into the shell of the host by sessile gastropods:
Hipponyx, Recent
Gen. indet., Cretaceous
Cirripedia:
Balanus, Recent (cardinal side pointing upwards)
Annelida:
Serpula, Upper Cretaceous
(Adapted from Schmid, 1949; Müller, 1952; and Seilacher, 1954)

taceous echinoids. As these epizoans could become attached only after the echinoderm had died and had lost its spines, they have no bearing on its ecology. However, they can be used to determine the position (or several positions), in which the dead echinoid lay. The same holds true for belemnite rostra, which remained covered by soft parts while the belemnite was alive, but often were incrusted after death (Müller, 1952).

On the essentially bare shells of lamellibranchs and brachiopods, premortal incrustation is easier and more common. For these shells the orientation of epizoans can be used to deduce the attitude of the living host. Some examples for such analyses are given in text-fig. 2.

It should be noted that it is not necessary to exactly identify the epizoans nor to know their specific slope orientation beforehand. If epizoans of the same kind occur on both valves or on both flanks of strong ribs or on different sides of a rounded body, even completely unknown species may be used (text-fig. 2-c). To find the original position of the incrusted specimen, one has merely to turn it to such a position that all epizoans

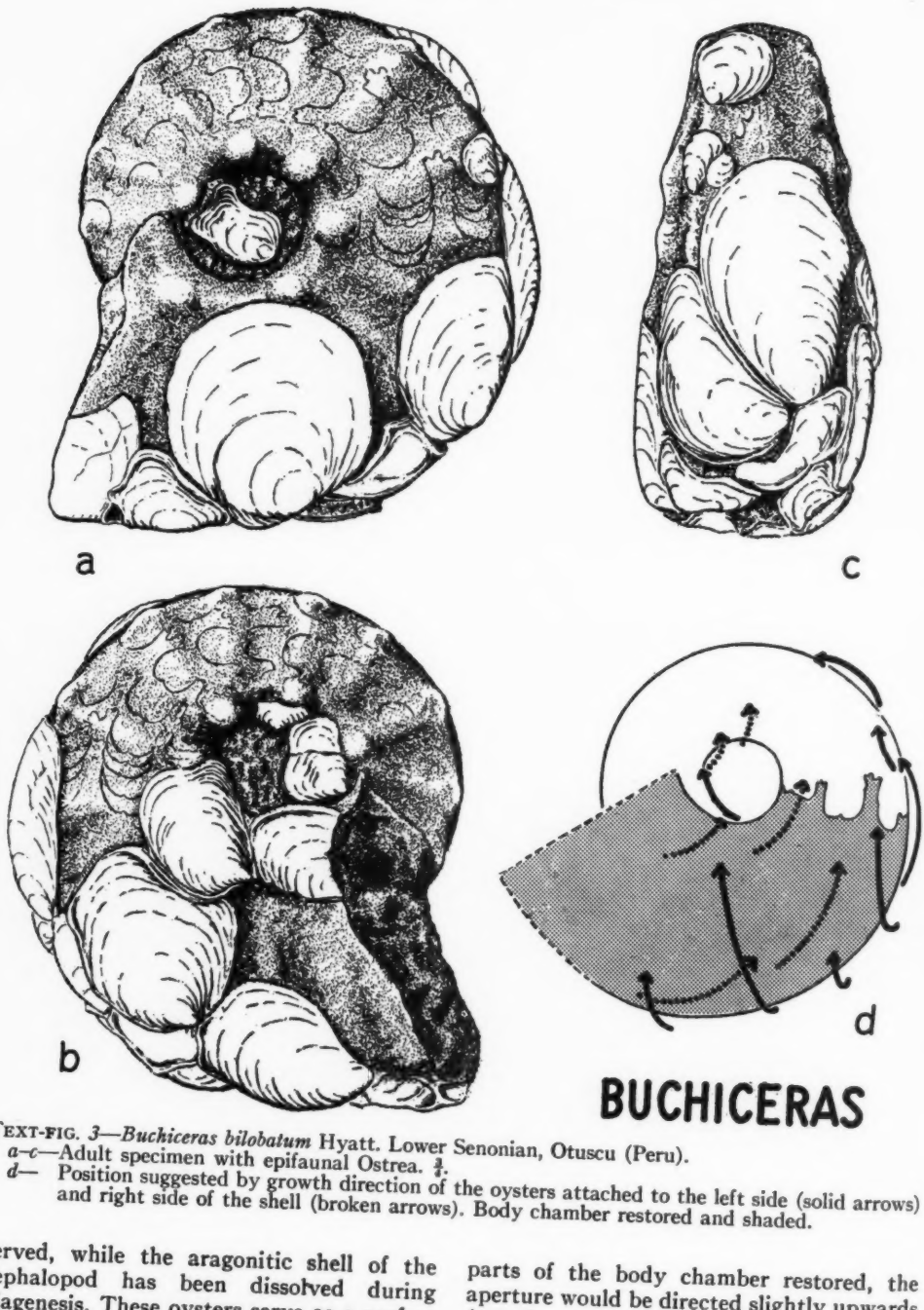


TEXT-FIG. 2—Attitude of some fossil pelecypods as derived from the orientation of their epifauna.
a–b—*Lima lineata* (Schlotheim), Middle Triassic, Germany. ×1. a) with *Alectryonia*, epifauna of four shells drawn on one specimen. b) with *Discinisca* and *Placunopsis* attached.
c— *Gervilleia hartmanni* Goldfuss with epifaunal *Discinisca*. The shell of the pelecypod is thickened on the ventral side, to make this position more stable. Middle Jurassic, Germany. ×½.
d— *Exogyra imbricata* Krauss, with impression of unknown gastropods on the left valve. Lower Cretaceous, South Africa. ×½.
e— *Gryphaea arcuata* (Lamck.), with young shell of the same species attached. Lower Jurassic, Germany. ×½.
(All after Seilacher, 1954)

of the same species lie with their axes at the same angle to the local slope. This angle may in turn give a clue to the taxionomic identification of the epizoans, especially if true and false "oysters" are to be distinguished (text-fig. 1).

OYSTERS ON *Buchiceras*

The specimen under discussion (text-fig. 3) is incrusted on both flanks and on the external side by many small oysters, all of which seem to be of the same kind. The oysters had calcitic shells which are pre-



TEXT-FIG. 3—*Buchiceras bilobatum* Hyatt. Lower Senonian, Otuscu (Peru).
a–c—Adult specimen with epifaunal Ostrea. ¾.
d— Position suggested by growth direction of the oysters attached to the left side (solid arrows) and right side of the shell (broken arrows). Body chamber restored and shaded.

served, while the aragonitic shell of the cephalopod has been dissolved during diagenesis. These oysters serve as a perfect example of slope orientation which allows the ammonite to be reorientated in the position shown by the figure. With the lost parts of the body chamber restored, the aperture would be directed slightly upwards (text-fig. 3-d). This agrees well with the restorations of similar forms which Trueman (1941, fig. 14) gave on a theoretical basis.

No doubt the oysters grew on the shell

while it was still afloat and not yet lying on the ground; otherwise the epifauna would not be equally developed on both flanks and on the ventral side of the living chamber. There might be some doubt whether the incrustation was pre- or post-mortal since none of the oysters was invested by the ammonite's growth. However, the oysters are too large to be only post-mortal incrustation. According to Kobayashi (1954, p. 43) the empty shells of recent *Nautilus* stay afloat for several months. Ammonite shells were more delicate and probably sank earlier, which view is also favored by the restriction of certain ammonites to certain types of sediments and their absence in others (Scott 1940, p. 315). Since the oysters needed much more than that time to reach their size (several years, according to Wagner 1936, p. 160), we may safely conclude that they grew on the living ammonite.

Another problem is posed by the fact that orientation is so uniform. Every spot on a growing ammonoid shell constantly changes its position relative to gravitation. Consequently, epizoans should have different orientation according to their time of attachment. They should also be smaller on the younger parts of the ammonite shell. The contrary is true with our specimen, which was adult, to judge from its crowded suture lines. This means that the oysters became attached only after the growth of the ammonite had ceased, but still the host lived long enough for them to reach a considerable size. If it took between one-half and three years for the last whorl of an ammonite to grow, at least an equal lapse of time should be added for the duration of the adult stage.

Our specimen also gives a certain idea about the mode of life of *Buchiceras*. The pseudoceratitic suture line, so clearly seen in our specimen, was explained by Spath (1919, p. 30) as the result of benthonic life. In a crawling *Buchiceras* the ventral side of the body chamber would have constantly scraped the ground. This is improbable, because the oysters preferred rather than avoided this ventral side. *Buchiceras* probably was neither a rapid swimmer nor truly benthonic, but rather floated and swam slowly close to the sea floor.

Our conclusions about the ecology of *Buchiceras* are not very surprising. They merely confirm a concept which is already accepted by most paleontologists for the stock of coiled nautiloids and ammonoids. The method may become more important, however, as a key to the still controversial ecology of uncoiled and aberrant types. So far no material is available to tackle this problem, but it is hoped that this note will stimulate the search for adequate specimens both in the field and in collections.

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GENERIC NAMES FOR AMMONOIDEA PUBLISHED DURING THE PERIOD 1758–1954

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ABSTRACT—Generic names used for Ammonoidea during the period 1758–1954 but not included in Volume L of the Treatise on Invertebrate Paleontology are listed and, in most cases, interpreted along similar lines to those used in the Treatise. The list comprises 72 available names and 39 that have been suppressed.

ONE of the major difficulties confronting the modern paleontologist is the time-consuming problem of keeping abreast of and mastering the taxonomic nomenclature of his particular group, in order that he might view as a whole the state of knowledge of that group and use his taxonomic terms correctly. For research workers on Ammonoidea, genus-group nomenclature is in many ways the most important, and, after almost 200 years of its elaboration, a comprehensive survey has recently been published in the Ammonoidea volume of the Treatise on Invertebrate Paleontology (volume L, Moore (editor), 1957). Undoubtedtly this is the greatest single aid yet provided to further research on this group. As well as giving a list of almost every genus-group name ever proposed for Ammonoidea, the Treatise also sets out under one cover a family-group classification and synonymy at genus level that is the considered opinion of the acknowledged world's experts, together with sufficient morphological and stratigraphical information and figures to give an adequate guide to each genus.

In view of the possiblity that a revised edition of the Treatise may be produced in the future, it is of great importance that efforts be made to collect together every generic name applied to Ammonoidea up to the end of 1954 (the last year surveyed comprehensively by the Treatise). This paper is a further stage towards that end; it lists those genera and subgenera which for various reasons were not included in the Treatise, and also those that have been officially suppressed by the International Commission on Zoological Nomenclature. Approximately one half of the following list was obtained when the card-index of ammonoid genera left to the British Museum (Natural History) by the late Dr. L. F. Spath was checked against the Treatise. The remainder have been obtained from various sources, including the Zoological Record, Neave's Nomenclator Zoologicus (1939–50), and by correspondence with the following specialists to whom the author wishes to extend his thanks: Dr. J. C. Callomon, Dr. R. Casey, Dr. D. T. Donovan, Dr. J. M. Hancock, Dr. M. R. House, Dr. B. Kummel, Dr. W. H. C. Ramsbottom, Dr. E. T. Tozer, and Mr. C. W. Wright. In order to obtain uniformity, details under each genus are given in the style used in the Treatise.

Unfortunately, although prolonged search has been made, it has not been possible to see copies of the following Chinese and Russian papers, which contain new generic names: Chao, 1950; Glazunova, 1953; Librovitch, 1946; Popov, 1945 and 1946; Voinova, 1947. These are quoted in full in the main part of the paper and all the new generic names in these papers are thought to be included, but not always interpreted. Most of the interpretations have been taken from the following work: Yu. A. Orlov (Chief editor). Principles of Palaeontology. Gazetteer for Palaeontology and Geology in the U.S.S.R. in fifteen volumes. Mollusca—Cephalopoda II. Ammonoidea (Ceratites and Ammonites). 358 pp., 71 pls. Moscow, 1958 (In Russian). This work is a comprehensive survey of Russian language work and nomenclature on Mesozoic ammonoids.

GENERIC NAMES PUBLISHED UP TO THE END OF 1954, AND NOT LISTED IN THE TREATISE ON INVERTEBRATE PALEONTOLOGY, VOLUME L, AMMONOIDEA

Full references are given where the genus is not in Neave's Nomenclator Zoologicus

(1939–50). Numbers prefixed by "L" refer to page numbers in the Treatise.

1. *Acuariceras* Spath, 1933.

Type species: *Baculites acuarius* Quenstedt, 1847. [=*Leioceras* Hörnes, 1884 (obj.) (*non* Hyatt, 1867)].

Dwarf form; conch straight except for slightly curved apical end; no ribs. *Callovian*, Ger.-Aus. Family Spiroceratidae (L205).

2. *Agastrioceras* Schmidt, 1938.

Type species: *Glyphioceras subcrenatum* var. *carinatum* Frech, 1902.

Similar to *Gastrioceras*, but with a carinate venter. *Namurian*, Europe. Family Neoicoceratidae (L61).

3. *Amphipopanoceras* Voinova, 1947, Atlas of the guide faunas of the fossil faunas of the U.S.S.R., vol. 7, Trias.

Type species: *A. dzeginensis* Voinova, 1947.

As figured by Orlov, 1958, p. 49, text-fig. 42, pl. 15, fig. 3, like *Megaphyllites*, but larger, and with more highly developed suture-line. Family Megaphyllitidae (L179).

4. *Archoceras* Schindewolf, 1938, *Jahrb. Preuss. geol. Land.*, v. 58, p. 243.

Type species: *A. paeckelmanni* Schindewolf, 1938.

Suture-line as in Middle Devonian *Anarcestes* (*Anarcestes*), but conch serpenticone with depressed whorls and periodic constrictions; occasionally with paired external furrows. Generally considered to be a possible ancestor for the Clymeniina. See Donovan, 1943, *Proc. Bristol. Nat. Soc.*, ser. 4, v. 9, p. 375. *U. Devonian*, Ger.-Eng.-Mor.-Alg.-?Amer. (*A.*(?) *wabashense*). Subfamily Anarcestinae (L31).

5. *Balduroceras* Bodylevsky, 1940 (reference not known).

Type species: *Ammonites balduri* Keyserling, 1846.

Objective synonym of *Styracoceras* Hyatt, 1903 (L279).

6. *Bashkirites* Librovitch, 1947, *Bull. Soc. Nat. Moscow, Geol.*, v. 22, no. 5, p. 60.

Type species: *B. discoidalis* Librovitch, 1947; first figured Librovitch, 1957, *Ann. Soc. Pal. Russia*, v. 16, p. 251.

Resembles *Hudsonoceras* in shape and ornament, but lacks the ventro-lateral sulcus and has stronger spiral striae.

L. Carb. (*U. Mississippian*), Russia. Subfamily Girtyoceratinae (L59).

7. *Biasaloceras* Drushchitz, 1953, *Vestnik Moscow University*, no. 6, p. 157.

Type species: *Lytoceras subsequens* Karakasch, 1907.

Subjective synonym of *Pterolytoceras* Spath, 1927, family Lytoceratidae (L196).

8. *Bilinguites* Librovitch, 1946, Материалы ВСЕГЕИ (*Materials of the All-Union Geological Institute*), *General series*, v. 7, p. 79.

Type species: *Reticuloceras superbilingue* Bisat, 1924.

See Ramsbottom, 1957, *Geol. Mag.*, v. 94, p. 310.

Subjective synonym of *Reticuloceras* Bisat, 1924, subfamily Goniatitinae (L56).

9. *Bœhmiceras* Grigorieva, 1938, The Lower Valanginian ammonite fauna from the basin of the White River on the northern slope of the Caucasus. *Azov and Black-Sea Geological Survey. Materials on the Geology and uses of fossils, Rostov-on-Don*, vol. 1, pp. 83–122.

Type species: *Hoplites* (*Blanfordia*) *boehmi* Uhlig, 1910.

Like *Blanfordiceras*, but has stouter whorls, larger primary ribs and develops lateral tubercles. Subgen. of *Blanfordiceras* Cossman, 1907 (L352). ?*U. Tithonian*, Spiti, Russia.

10. *Celaeceras* Hyatt, 1883.

Type species: *Goniatites praematurus* Barrande, 1877.

Conch sub-involute, suture with ventral, ventro-lateral and wide latero-umbilical lobes. *M. Devonian* (G_1), Czech. Subfamily Pinacitinae (L31).

11. *Ceratotuberculus* Imlay, 1938.

Type species: *C. casitensis* Imlay, 1938.

Subjective synonym of *Saynoceras* Munier-Chalmas & de Lapparent, 1893, subfamily Olcostephaninae (L347).

12. *Chandomirovia* Sazonov, 1951, *Bull. Soc. Nat. Moscow, Geol.*, v. 26, no. 5, p. 61.

Type species: *C. ilekensis* Sazonov, 1951.

Lower Valanginian, Russia. Subjective synonym of *Tollia* (L344).

13. *Clionitites* Strand, 1929.

Nom. nov. for *Clionites* Mojsisovics, 1893 (*non* Morris, 1850—sponge), family Clionitidae (L160).

The family name Clionititidae nov. is here proposed in substitution for Clionitidae Arabu, 1932, to include the same genera as are referred to the latter family in the Treatise.

14. *Cluthoceras* Currie, 1954, *Trans. Roy. Soc. Edin.*, v. 62, p. 560.

Type species: *C. truemani* Currie, 1954.

Like *Anthracoceras*, but with suture-line like juvenile *Muensteroceras*. *Namurian* (E_2), Scot. Subfamily Goniatitinae (L55).

15. *Coloboceras* Crickmay, 1927 (*non* Trouessart, 1889—Arachnida).

Type species: *Sonneratia stantoni* Anderson, 1902.

See Crickmay, 1953, *J. Pal.*, v. 27, pp. 879–880. *L. Albian* (Mammillatum Zone), N. America.

Senior, pre-occupied, subjective synonym of *Lemuroceras* Spath, 1942, subfamily Gastroplitinae (L400).

16. *Cravenoceratoides* Hudson, 1941, *Proc. Yorks. Geol. Soc.*, v. 24, p. 282.

Type species: *Goniatites nitidus* Phillips, 1836.

Differs from *Cravenoceras* in having stronger, dichotomizing ribs, and is confined to E_2 of the Namurian. *Namurian* (E_2), England. Subfamily Goniatitinae (L55).

17. *Daghestanites* Glazunova, 1953, Aptian and Albian ammonites of Kopet-Dag, Malogo and Bol'shogo Balkhanov and Mangyshlaka. Труды ВСЕГЕИ (*All-Union Geological Institute*).

Subgenus of *Anahoplites* Hyatt, 1900, (L396) according to Orlov, 1958, but may be quite different.

18. *Daxatina* Strand, 1929.

Nom. nov. for *Dawsonites* Böhm, 1903 (*non* Scudder, 1895—insect), family Trachyceratidae (L160).

19. *Devonopronorites* Bogoslovsky, 1954, *C. R. Acad. Sci. U.R.S.S.*, (N.S.) v. 97, p. 323.

Type species: *D. ruzhencevi* Bogoslovsky, 1954.

U. Devonian, Rudnii Altai, Russia. ? Family Pronoritidae (L71).

20. *Digitophyllites* Chao, K. 1950, Some new ammonite genera of Lower Triassic from Western Kwangsi. *Pal. Novitates, Pal. Soc. China*, no. 5.

Family Megaphyllitidae (L179), according to Orlov, 1958.

21. *Dombarites* Librovitch, 1947, *Bull. Soc. Nat. Moscow, Geol.*, v. 22, no. 5, p. 56.

Type species: *D. tectus* Librovitch, 1947; first figured Librovitch, 1957, *Ann. Soc. Pal. Russia*, v. 16, p. 258.

Said to be a link between *Proshumardites* and *Goniatites*, but suture-line and shape of conch are typical of *Goniatites*.

Subjective synonym of *Goniatites* de Haan, 1825 (L56).

22. *Donetzoceras* Librovitch, 1946, Материалы ВСЕГЕИ (*Materials of the All-Union Geological Institute*), General Series, v. 7.

Nomen nudum.

23. *Eomeekoceras* Sun, 1939, Fortieth Anniversary Papers, National University of Peking, v. 1, p. 45.

Type species: *E. kwangsiense* Sun, 1939.

Probably Permian age, but not recognizable.

24. *Epechioceras* Trueman & Williams, 1925.

Type species: *E. expansum* Trueman & Williams, 1925.

Subjective synonym of *Paltechioceras* Buckman, 1924, family Echioceratidae (L244).

25. *Euthymiceras* Grigorieva, 1938, *loc. cit.* (genus 9).

Type species: *Ammonites euthymi* Pictet, 1867.

Similar to *Protacanthodiscus*, but primary ribs more distant throughout and venter tabulate and smooth with rows of large ventro-lateral tubercles.

Subfamily Berriasellinae (L350).

26. *Fengshanites* Chao, 1950, *Pal. Novitates, Pal. Soc. China*, no. 5.

Subfamily Columbitinae (L139), according to Orlov, 1958.

27. *Ferganoceras* Librovitch, 1947, *Bull. Soc. Nat Moscow, Geol.*, v. 22, no. 5, p. 56.

Type species: *F. elegans* Librovitch, 1947;

first figured Librovitch, 1957, *Ann. Soc. Pal. Russia*, v. 16, p. 254.

Based on immature specimen. Subjective synonym of *Eumorphoceras* Girty, 1909, or *Girtyoceras* Wedekind, 1918 (L59).

28. *Genodiscus* Smith, 1932.

Type species: *Xenodiscus lidacensis* Welter, 1922 (= *Celtites fortis* Frech, 1905).

Invalid under Art. 25 as no diagnosis was given; in any case it is a subjective synonym of *Anakashmirites* Spath, 1930, family Kashmiritidae (L142).

29. *Germanites* Mascke, 1906.

Nomen nudum; but = *Germanites* Westermann, 1954.

30. *Haugiceras* Cossmann, 1900.

Nom. nov. for *Prionoceras* Hyatt, 1884.

Objective synonym of *Prionoceras* Hyatt, 1884, subfamily Imitoceratinae (L49).

31. *Hesperites* Pompeckj, 1895.

Type species: *H. clarae* Pompeckj, 1895.

Much resembles Lower Liassic Schlotheimiidae, especially *Charmasseiceras* Spath, 1924, but said to come from the Rhaetic at Hochfelln, Germany. Not recognizable.

32. *Homolsomites* Crickmay, 1930.

Type species: *H. poecilochotomus* Crickmay, 1930.

Type specimens refigured by Imlay, 1956, *Journ. Pal.*, v. 30, p. 1143–46, pl. 120, who upheld *Homolsomites* as a valid genus. However, it shows no morphological differences from *Neocraspedites* with which it is associated in the same beds.

Subjective synonym of *Neocraspedites* Spath, 1924, subfamily Polyptychitinae (L348).

33. *Hoplitocrioceras* Giovine, 1950, *Rev. Asoc. Geol. Argentina*, v. 5, no. 2, p. 49.

Type species: *H. gentilii* Giovine, 1950.

Technically invalid because *H. gentilii* (the only species) is not definitely designated as the type species. *U. Valanginian—L. Hauterivian*, Argentina.

Subjective synonym of *Distoloceras* Hyatt, 1900, subfamily Neocomitinae (L361).

34. *Hoploancyloceras* Nowak, 1913, *Bull. Acad. Sci. Cracovie, Cl. Sci. Mat. Nat.*, p. 382.

Nomen nudum

35. *Indigirites* Popov, Yu. N., 1945, Distribution and paleontological characteristics of Middle Trias deposits of northeastern Asia. *Materials on the Geology and Economic Minerals of the north-eastern part of the U.S.S.R.*, no. 1. See also: The fauna of the Ladinian Trias from the vicinity of Oimekon. *Ibid*, no. 2.

36. *Kingoceras* Miller, 1944.

Type species: *K. kingi* Miller, 1944.

Conch evolute, subdiscoidal, with sharpened venter and flat sides; umbilical edge nodose in early whorls, outer whorl smooth. Suture-line in *Treatise*, L132, fig. 163E. *U. Permian*, Mexico. Family Xenodiscidae (L130).

37. *Kwangsites* Sun, 1939, *op. cit.* (genus 23), p. 47.

Type species: *K. chui* Sun, 1939.

The only specimen is a 3 mm. diameter nucleus. Probably Permian, but not recognizable.

38. *Leioceras* Hörnes, 1884 (non Hyatt, 1867).

Objective, pre-occupied, senior synonym of *Acuariceras* Spath, 1933 (genus 1).

39. *Lilinthiceras* Diener, 1903.

No specific name was proposed for the specimens on which the genus was founded; they were small and indeterminate, with some resemblance to the Upper Triassic Clionititidae, but were said to have come from the Permian of the central Himalayas. Not recognizable.

40. *Lingyunites* Chao, 1950, *Pal. Novitates, Pal. Soc. China*, no. 5. Family Paranoritidae (L137), according to Orlov, 1958.

41. *Maderia* Imlay, 1938.

Type species: *M. coronata* Imlay, 1938.

Subjective synonym of *Subastieria* Spath, 1823, family Olcostephaninae (L347).

42. *Malbosiceras* Grigorieva, 1938, *loc. cit.* (genus 9).

Type species: *Ammonites malbosi* Pictet, 1867.

Similar to *Protacanthodiscus*, but ribs become divided into more distant, bituberculate primaries, with many intercalated secondaries which are continuous across the

venter and develop ventro-lateral tubercles at large sizes.

Subfamily Berriasellinae (L350).

43. *Metaxytes* Mascke, 1907.

Nomen nudum, but probably = *Normannites* Munier-Chalmas, 1892 (L289).

44. *Meunieria* de Gregorio, 1922, *Ann. Geol. Pal. Gregorio*, v. 36, p. 16 (*non* Kieffer, 1904).

Objective synonym of *Cyrtosiceras* Hyatt, 1900, subfamily Streblitinae (L284).

45. *Mexicanoceras* Imlay, 1938.

Type species: *M. kanei* Imlay, 1938.

Like *Subastieria*, but with ventral groove developing on all except innermost whorls. *L. Hauterivian*, Mexico. Subfamily Olcostephaninae (L347).

46. *Mzezzemceras* Basse, 1954, *Bull. Soc. géol. France*, ser. 6, v. 3, p. 868.

Type species: *Coahuilites* (*Mzezzemceras*) *pervinquieri* Basse, 1954.

Suture-line as in *Coahuilites* (*Coahuilites*), from which it differs in being more compressed with a sharpened venter, and in having much less prominent ribs and tubercles. Subgenus of *Coahuilites*. *L.-M. Maastrichtian*, South Tunisia. Family Sphenodiscidae (L437).

47. *Neoposiella* Mahmoud, 1953, *C. R. Somm. Séan. Soc. géol. France*, 1953, p. 286 (1952, *ibid*, p. 119, *nom. nud.*).

Type species: *Silesites nepos* Douville, 1917.

Technically invalid because *N. nepos* is not definitely designated as the type species. *L.-M. Albian*, Egypt, Madagascar. Subjective synonym of *Neosilesites* Breistroffer, 1952, family Silesitidae (L374).

48. *Osmanoceras* Kittl, 1904.

Type species: *O. undulatum* Kittl, 1904.

Only known specimen small, but it is probably a *Beyrichoceras*.

?Subjective synonym of *Beyrichoceras* Foord, 1903, subfamily Goniatitinae (L57).

49. *Paracibolites* Hayasaka, 1947, *Acta. Geol. Taiwanica*, v. 1, p. 32.

Type species: *P. costatus* Hayasaka, 1947.

Said to differ from *Cibolites* in having the third lateral saddle, not the third lateral lobe, on the umbilical seam. Such forms are, however, included in the range of variation of *Cibolites*. *U. Permian*, Chechiang, China.

Subjective synonym of *Cibolites* Plummer & Scott, 1937, family Xenodiscidae (L132).

50. *Paradinarites* Chao, 1950, *Pal. Novitates, Pal. Soc. China*, no. 5.

Family Dinaritidae (L147), according to Orlov, 1958.

51. *Paragattendorfia* Schindewolf, 1924.

Type species: *P. humilis* Schindewolf, 1924.

Claimed to differ from *Gattendorfia* in that the umbilical lobe is halved by the umbilical seam, by the narrow and deeper dorsal lobe elements and by the absence of constrictions.

Subjective synonym of *Gattendorfia* Schindewolf, 1920, subfamily Imitoceratinae (L50).

52. *Paraindigirites* Popov, 1945. Same references as for *Indigirites* (genus 35).

53. *Paratornoceras* Hyatt, 1900.

Type species: *Goniatites lentiformis* Sandberger, 1857.

Sandberger's species was first figured by Kayser (1873, *Zeit. Deutsch. Geol. Ges.*, v. 25, p. 612, pl. 19, fig. 1). Conch lenticular with sharpened venter; umbilicus small in juvenile with nodes on umbilical edge, almost closed in adult. Commonly considered a *Dimeroceras* (e.g. Schindewolf, 1923, *Neues. Jahrb. f. Min.*, v. 49, p. 339) of which it would be a subjective synonym. *U. Devonian*, Ger.-N. Africa. Subfamily Cheiloceratinae (L48).

54. *Paroxytropidoceras* Breistroffer, 1952, *C. R. Somm. Séan. Soc. géol. France*, 1952, p. 267.

Type species: *Brancoceras carinatum* Collignon, 1949.

Nomen nudum, generic characters not given.

Family Brancoceratidae (L402).

55. *Picenia* Fossa-Mancini, 1919.

Type species: *P. undulata* Fossa-Mancini, 1919; *Toarcian*, Apennines.

Subjective synonym of *Phymatoceras* Hyatt, 1867, subfamily *Phymatoceratinae* (L265).

56. *Pomeliceras* Grigorieva, 1938, *loc. cit.* (genus 9).

Type species: *Ammonites breveti* Pomel, 1889.

Differences from *Malbosiceras* Grigorieva, 1938, are not more than specific. Subjective synonym of *Malbosiceras*.

57. *Proharpoceras* Chao, 1950, *Pal. Novitates, Pal. Soc. China*, no. 5.

Family Tropiceltitidae (L171), according to Orlov, 1958.

58. *Pronannites* Haug, 1898.

Type species: *Goniatites inconstans* de Koninck, 1880 (*non* Phillips, 1836—*Reticuloceras*).

Subjective synonym of *Muensteroceras* Hyatt, 1884, subfamily Goniatitinae (L57).

59. *Prosageceras* Frech, 1901.

Type species: *Propinacoceras beyrichi* Gemmellaro, 1887, here designated.

Objective synonym of *Propinacoceras* Gemmellaro, 1887, subfamily Medlicottiinae (L74).

60. *Protoclymenia* Schindewolf, 1923, *Centrabl. f. Min. Geol. Pal., Jahr.* 1923, p. 62 (table).

Nomen nudum.

61. *Pseudharpoceras* Waagen, 1895, *Pal. Indica*, ser. XIII, v. 2, pt. 1, p. 130 (1893—*nomen nudum*).

Type species: *P. spiniger* Waagen, 1895.

Spath (1951, Cat. Foss. Ceph. B. M., part V, p. 8) said it may be an Upper Liassic Hildoceratid. However, the only known specimen was said to come from the topmost Trias of the Salt Range; it has the ornament and the suture-line of the family Hellenitidae (L149), but it is too worn for exact identification.

62. *Pseudohauerites* Arthaber, 1911.

Type species: *Amm. rarestriatus* Hauer, 1849.

Objective synonym of *Hauerites* Mojsisovics, 1893, family Cyrtopleuritidae (L165).

63. *Pseudohomoceras* Librovitch, 1947, *Bull. Soc. Nat. Moscow, Geol.*, v. 22, no. 5, p. 61.

Type species: *Goniatites smithi* Brown, 1841.

Nomen nudum according to Art. 25, for the generic characters are not given (see Ramsbottom, 1957, *Geol. Mag.*, v. 94, p. 310.)

64. *Pseudotirolites* Sun, 1939, *op. cit.* (genus 23), p. 44.

Type species: *Tirolites asiaticus* Jaekel, 1929 (first figured Sun, 1939).

Probably Permian, but not recognizable.

65. *Renngarteniceras* Grigorieva, 1938, *loc. cit.* (genus 9).

Type species: *R. renngarteni* Grigorieva, 1938.

Subjective synonym of *Neocosmoceras* Blanchet, 1922 (L358).

66. *Schuchertites* Smith, 1903.

Type species: *S. grahami* Smith, 1903.

Said to come from the Upper Coal Measures, Cisco Formation, Young Country, Texas. However, the suture-line is that of a Cretaceous pseudoceratite, and the morphology is that of the genus *Engonoceras* which occurs in many parts of Texas (this relationship was pointed out by Spath, 1934, Cat. Foss. Ceph. B. M., part IV, p. 14.).

Subjective synonym of *Engonoceras* Neumayr & Uhlig, 1887, family Engonoceratidae (L388).

67. *Surites* Sazonov, 1951, *Bull. Soc. Nat. Moscow, Geol.*, v. 26, no. 5, p. 59.

Type species: *S. pechorensis* Sazonov, 1951.

Berriasian, Russia. Synonym of *Paracraspedites*, subfamily Craspeditinae (L342).

68. *Synwocklumeria* Librovitch, 1947, *Bull. Soc. Nat. Moscow, Geol.*, v. 22, no. 5, p. 52.

Type species: *S. bashkirica* Librovitch, 1947; first figured Librovitch, 1957, *Ann. Soc. Pal. Russia*, v. 16, p. 247.

Subjective synonym of *Wocklumeria* Wedekind, 1918 (L42), which it resembles in shape, ornament, suture-line and age.

69. *Traneceras* Hyatt, 1903, *Mon. U. S. Geol. Surv.*, v. 44, p. 25.

Nomen nudum.

70. *Trigonogastrioceras* Librovitch, 1947, *Bull. Soc. Nat. Moscow, Geol.*, v. 22, no. 5, p. 63.

Type species: *T. uralicum* Librovitch, 1947; first figured Librovitch 1957, *Ann. Soc. Pal. Russia*, v. 16, p. 256.

The specimen on which the genus is based is deformed on the venter, but is otherwise like *Paralegoceras*.

Subjective synonym of *Paralegoceras* Hyatt, 1884 (L65).

71. *Tuyangites* Chao, 1950, *Pal. Novitates, Pal. Soc. China*, no. 5.

Family Tropiceltitidae (L171), according to Orlov, 1958.

72. *Wrightia* Gemmellaro, 1886 (*non* Agassiz, 1862—Coelenterata).

Type species: *Harpoceras* (*Wrightia*) *alternans* Gemmellaro, 1886 (not figured); *U. Pliensbachian—L. Toarcian*, Sicily.

Syntypes figured Fucini, 1929, *Pal. Italica*, v. 29, p. 45, pl. 4, figs. 15–16.

Subjective senior synonym of *Protogrammoceras* Spath, 1913, subfamily Harpoceratinae (L258).

The following generic names have been officially suppressed for the Law of Priority but not for the Law of Homonymy:

73. *Planulites* Lamarck, 1801.	ICZN Opinion 304
74. *Orbulites* Lamarck, 1801.	
75. *Pelagus* Montfort, 1808.	
76. *Ellipsolithes* Montfort, 1808.	
77. *Globites* de Haan, 1825.	
78. *Ammonites* Bruguière, 1789.	ICZN Opinion 305
79. *Planites* de Haan, 1825.	ICZN Opinion 504
80. *Biplices* Siemiradzki, 1891.	

81. About 31 generic names were proposed by Sobolew in 1914 in the following two papers: Skizzen zur Phylogenia der Goniatiten. *Izvestija Varshavskago Politekhricheskago Instituta*, 1914, fasc. 1; Ueber Clymenien und Goniatiten. *Pal. Z.*, v. 1, p. 348ff. All the new generic names in both papers were suppressed by the I.C.Z.N. in Opinion 132.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 1, P. 201–202, JANUARY, 1960

NOMENCLATURAL NOTE

USE OF THE TERM "VARIETY" IN PALEONTOLOGY

G. WINSTON SINCLAIR
Geological Survey of Canada

Most of us learn a set of routines which we use in carrying on our work, do not question them once they have been adopted, and usually assume that these are the ways in which everybody does things. It is often a shock to find that workers in other fields, or with different backgrounds, do not share the premises we take for granted.

Thus, most American paleontologists have learned to use the category "variety," know what they mean by it, and find it clear. I think most would be surprised to be told that no one else uses this word in the same way that we do, and, indeed, that workers in many fields are horrified at our practice.

This divergence in usage came into the open at the Copenhagen Colloquium on Nomenclature, 1953, when the paleontologists present were faced with a rule proposing that varieties should have no status whatever in nomenclature. Our protests were sufficiently strong that the new rule recommended at that time made an exception for varieties of fossils. (This matter had come up in 1948 in Paris, but the Paris meetings produced no new Code, and we could not foresee that the Copenhagen meeting would be equally barren of any final results.)

At the London meetings, 1958, the feeling was quite strongly expressed that any exceptions to the Rules for the convenience of particular groups of workers were bad. I do not think there will be much argument with this point of view. A moment's reflection on the large number of borderline fields of study will suggest the confusion that would result were different rules to apply to, say, Recent and Pleistocene mollusks, or to forams and ostracods. The ideal must be a set of Rules which will be the same for all groups on which a zoologist may be working. (There is, in fact, an opinion that the zoological, botanical and bacteriological Codes should be brought closer together, and committes are examining the possibility of doing so.)

A new Code is now being drafted, to incorporate the results of the London meetings, and it is not possible at present to know just what form it will take. But whatever the wording of the Rules, this particular problem is one which paleontologists can solve overnight, if they want to. Let us try to see clearly just what is involved.

A group of animals sufficiently similar in form, blood chemistry, chromosome structure, etc. to permit interbreeding and consequent essential homogeneity throughout its range, and at the same time sufficiently distinct that we can tell it from other groups (by study of morphology, or serology, or breeding experiments, etc.) we think of as a natural taxonomic group. Such a group has a geographic range, and exists throughout a period of time. That is, it may be found in other places and at other geological horizons than that from which it was first described. Therefore we must agree on what to call it, so that we may talk about it and be understood. That is what the rules of nomenclature are all about. Were it not for this possibility of extension of range no harm could result from separate names for England and for France, for Recent and for Pleistocene. Universal rules are needed because our animals may be universal. These natural taxonomic units for which we have agreed names are, at the lower level, genus, species and subspecies.

In most branches of zoology, including paleontology, it is necessary to be able to refer to quite different kinds of concepts. We find mutants, sports, aberrations, monsters, variations of one kind or another which are individual, and although they may occur in many individuals do not mark off those individuals as a taxonomic unit. It is for some such departures from the norm that most zoologists use the term "variety," and it is as such that they interpret the term

when they read it in a paper on fossils. These are the infrasubspeciec groups of the nomenclaturalist. The names given to them are not universal, but special and local. They are not considered part of zoological nomenclature, do not come under the rules of nomenclature, and do not compete with names which do.

It seems to me, from a casual survey of recent issues of the JOURNAL, that usually when we use the term "variety" we really mean what other people call a subspecies. Certainly, when we have a form of a species which always occurs in bed B, from which the typical form is absent, or when we have a form which occurs in Idaho and differs slightly but constantly from the original New York form, then we are dealing with stable groups, which should be recognized as such. The simplest way to be sure that this meaning is understood by the reader is to call the new form a subspecies.

We do have "varieties" in the zoological sense, but at present their existence is obscured by the ambiguity of the term. Thus in a population of trilobites there may be some which are wider than the rest. We may think them to be females, or senile, or gluttons, but we do not think of them as separable taxonomically: they are all the same species. Here the term variety would be appropriate, were it not for its confused history. Under the circumstances, the term "form" might best convey the sense. May I here interject my personal opinion, that nothing is gained by introducing Latin names for such categories. It is quite as meaningful to speak of "wide form" or "spiny form" as it is to say *forma lata* or *forma spinosa*, and the risk of confusion in synonymy or homonymy is avoided. (Too, most paleontologists are better at English than they are at Latin.)

And so my suggestion (to myself as well as to my colleagues, for what little wisdom I have in this matter has come to me late) is that we decide first of all if we are dealing with a natural unit. If we are, then let us call it a subspecies. If we are not, then let us make that opinion clear by the use of some unequivocal term, such as "form." The term "variety" we have used ambiguously for so long that it is no longer clear, especially if used with a latinized adjective, and I suggest that we drop it entirely.

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NOTICE

PLATES PER ARTICLE

We wish to call attention of prospective authors to the ruling of the Council of the Paleontological Society as reported in this issue. If an article contains more than 5 plates, the author must pay for all plates in excess. We hasten to add that the Society welcomes subsidy for any publishing. Contributions in support of an article will be acknowledged in a footnote.

ROBERT V. KESLING
ERWIN C. STUMM

CORRECTIONS

My article, "Paleoecology—Retrospect and prospect," which appeared in this *Journal* (v. 33, no. 5, p. 926–62) last September, contains the following significant errata:

p. 926, 2d quotation—add *in* before depth, delete period before dash.
p. 931, left column, 23d line—*burrows*, not furrows.
p. 938, left column, 26th line—*on* opposing, not of opposing
p. 953, right column, 5th line—after *or* add *because some element.*
p. 961—date for Teichert reference is *1958.*

PRESTON E. CLOUD, JR.

JOURNAL OF PALEONTOLOGY, V. 34, NO. 1, P. 203–207, JANUARY, 1960

REVIEWS

REVIEW OF "PRINCIPLES OF PALEONTOLOGY-HANDBOOK FOR PALEONTOLOGISTS AND GEOLOGISTS OF THE U.S.S.R., VOLUME 6, MOLLUSCA. CEPHALOPODA II: AMMONOIDEA (CERATITES AND AMMONITES), ENDOCOCHLIA: SUPPLEMENT, CONICONCHIA." MOSCOW, 1958. PRICE 55 RUBLES, 6 KOPEKS.[1]

JAMES L. CONNORS[2] AND ELLIS L. YOCHELSON[3]

This is the first volume to appear of a proposed series on Paleontology under the general editorship of Yurii Alexandrovich Orlov, an eminent vertebrate paleontologist of the Russian Academy of Sciences. It is sponsored by the Ministry of Geology and Mineral Resources, and the Ministry of Higher Education. As further proof that this is a major undertaking, a dozen Russian geological institutes and universities are acknowledged as assisting in preparation. The Handbooks are to be published by the Government Scientific Technical Press for Literature of Geology and Conservation of Mineral Resources.

The volumes planned and their editors are:

1. General discussion. Protozoa: D. M. Rauzer-Chernousova and A. V. Fursenko.
2. Porifera; Archaeocyathida; Coelenterata: B. S. Sokolov.
3. Mollusca-Testaces, Bivalva, Scaphopoda. Supplement-worms: A. G. Eberzin.
4. Mollusca-Gastropoda: V. F. Pchelintsev and I. A. Korobkov.
5. Mollusca-Cephalopoda I: Nautiloidea, Bactritidea, Ammonoidea (Agoniatites, Goniatites, Clymenida): V. E. Ruzhentzev.
6. Mollusca-Cephalopoda II: Ammonoidea (Ceratites and Ammonites), Endochochilia. Supplement-Coniconchia: N. P. Luppov and V. V. Druschitz.
7. Bryozoa, Brachiopoda: T. G. Sarycheva.
8. Arthropoda-Trilobita; Crustacea: N. E. Chernysheva.
9. Arthropoda-Trachea; Chelicerata: B. B. Rodendorf.
10. Echinodermata; Hemicordata: R. F. Hekker.
11. Agnatha; Pisces: D. V. Obruchev.
12. Amphibia; Reptilia; Aves: A. K. Rozhdestvenskii.
13. Mammalia: V. I. Gromova.
14. Algae; Bryophyta; Psilophytales; Lycopodiales; Equisetales; Filicales: V. A. Vakhrameev, G. P. Radchenko, A. L. Takhtadzhan.
15. Gymnospermae, Angiospermae: V. A. Vakhrameev, G. P. Radchenko, A. L. Takhtadzhan.

Professor Orlov has written us (January 8, 1959) that two volumes will be published in 1959; volume 1 (General Discussion and Protozoa) in the spring, and volume 8 (Crustacea and Trilobita) in the fall. Two other volumes, volume 7 (Bryozoa and Brachiopoda) and volume 4 (Gastropoda), are scheduled for the first half of 1960. There is no information when the remaining volumes will be published.

Volume 6 was collated June 1, 1957 and sent to the printers March 28, 1958. A copy was received in the library of the U. S. Geological Survey, August 15, 1958. It was issued in an edition of 6,000 which is large in comparison to some Russian publications on paleontology. The book has a hard green binding, with a diagram of a cephalopod impressed on the front cover. Page size is 10¼ inches by 8 inches; paper stock is white and of good quality. Except for the first few pages a double column format is used; the typography is fairly good with no observable broken type. The volume contains 190 pages of text, including 168 text figures and 6 pages of range charts; 78 plates and plate explanations; and a seven page index.

The major part of voume 6 is devoted to Mesozoic ammonoids, and contain contributions by the editors of the volume and 17

[1] Publication authorized by the Secretary of the Smithsonian Institution and the Director, U. S. Geological Survey.

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other authors. The text of 117 pages is followed by 5 pages of range charts and by 9 pages of bibliography in small type. One hundred-four text figures are included and 64 plates of halftones illustrate specimens.

This work invites comparison with volume 14 of the English language "Treatise on Invertebrate Paleontology" edited by R. C. Moore. However, the introduction to volume 6 of the Handbook clearly indicates that it is limited in scope to genera which have been found or might be found in the U.S.S.R. Descriptive treatment is limited to characteristic genera and makes no attempt to give complete coverage as does the Treatise. For some families, scope is somewhat greater than in others; apparently the phrase "might be found" has been interpreted differently by various authors. The introduction bears a footnote, stating that "Preparation of the present work would not have been entirely completed without the valuable summary of Ammonites in the 'Treatise on Invertebrate Paleontology,' part 14, with which the authors only became acquainted during the preparation of the present volume."

Pages 15 to 20 are devoted to brief accounts of terminology, morphology, principles of systematics, stratigraphic significance, and historical development of the study of ammonites. The Treatise devotes more than 60 pages to these and similar subjects. As volume 6 is the second projected volume for cephalopods, a more extensive treatment of the class can be anticipated in volume 5.

The Handbook contains descriptions of two suborders, 32 superfamilies, and 153 families. Except for the Otoceratáceae, these include exclusively Mesozoic genera. The equivalent part of the Treatise contains 5 suborders, 25 superfamilies, 156 families, and 120 subfamilies.

Furthermore, the various taxa do not always include the same genera in both volumes. In general, however, the arrangement of genera is similar. Incidentally, the Treatise uses the category subgenus for 363 names in the Mesozoic section; the Handbook, only once. The Handbook does not include Aptychi, which are given a separate section in the Treatise.

The format for generic description is similar to that of the Treatise. Generic name, author and date are given, followed by the type species with author and date. Next are the geologic and geographic occurrence of the type species, which are followed by the formal generic description, plate and text-figure references, and an approximation of the number of species in the genus. Finally, the geologic range and geographic distribution of the genus are presented.

Although only selected genera are described, in most families the last description is followed by a list of genera also included in the family. Accordingly, based on a superficial examination it is impossible to judge precisely how many genera are diagnosed. About 1350 names are included in the index, and probably 1200 apply to Mesozoic ammonoids, but these include homonyms, synonyms and genera not diagnosed. By comparison the Mesozoic section of the Treatise contains 1375 generic names, 363 subgeneric names, and about 700 synonyms and homonyms.

A spot check of generic diagnoses revealed that the Treatise and the Handbook are in agreement on most details, although the diagnoses in the Handbook are longer. Suprageneric diagnoses are also longer in the Handbook than in the Treatise. Apart from a few errors in dates of type species, there was very little disagreement observed between the Treatise and the Handbook; transliteration of several Russian authors' names differed in different sections of the Handbook. The Handbook includes relatively more suture pattern drawings in proportion to the number of genera included than does the Treatise: 382 in the Handbook against about 475 in the Treatise.

The plates include illustrations for 542 species representing 493 genera. With few exceptions each species is illustrated by an apertural and an umbilical view. In most cases Russian species are illustrated in preference to the type species of the genera. It also appears that available specimens were photographed in preference to reproductions from previously published illustrations. For some species this has resulted in poorer photographs than are already available. Where comparison can be made between the same illustration in the Treatise and the Handbook, the Russian figures seem darker and

slightly inferior. Even though the Russian photographs are printed on a heavy stock coated paper, the half-tone screen employed is coarser than that used for the Treatise.

The second part of the volume, occupying 44 pages, treats the subclass Endocochila or Coleoidea; it is prepared by G. Ya. Krymoholtz. Emphasis is placed on the Decapoda; only three pages are devoted to the Octapoda. Almost one-fourth of the text is devoted to discussion of ranges, morphology, and phylogeny. Ninety-five generic names were counted in this section; 68 are diagnosed, and 27 are listed under a family or subfamily. Fifty-six text figures illustrate this section. Almost 60 representative species, most of which are illustrated by 2 views, are on 7 plates. The bibliography, set in small type, occupies more than 3 pages.

The supplement under the heading ?Mollusca is devoted to the class Coniconchia and is written by G. P. Liashenko (or Ljaschenko) and V. A. Syssoiev. As this is the shortest part of the volume, containing only 11 pages and 8 text figures, a complete translation was prepared. Liashenko diagnoses the class and divides it into 2 orders: the Tentaculoidea and the Hyolithoidea. The first, written by K. Liashenko, contains 9 genera; and the second prepared by Syssoiev, 23 genera. Most of these genera have been named in the last 5 years by these 2 authors. Actually the class was proposed in 1957 by Liashenko and much of his material is presented without change. The Handbook has the advantage of being a uniform treatment assembled under one cover. Seven plates illustrate 33 species. Four are half-tones of Tentaculoidea; 3 are line drawings of Hyolithoidea.

The proposal of this class should be welcomed as a forward step. Many paleontologists have suggested that these forms are mollusk-like, but have placed them as *Incertae Sedis*. Although nothing is known of the soft parts, the shells of these few genera show many unique characters that point toward major classificatory rank. Further study is needed to determine if these two kinds of shells represented by *Hyolithes* and *Tentaculites* should be joined in one class. In passing, it should be noted that several lower Paleozoic nonseptate univalve genera are not included in the Coniconchia, but it cannot be determined if this omission is by intent or by oversight.

In summary, the Handbook is a useful volume. As the arrangement and format are similar to that of the Treatise, the volume is easy to follow in spite of the language barrier. Within its stated limitations, the Handbook appears to provide adequate detail.

POKORNÝ, VLADIMÍR, 1958, GRUNDZÜGE DER ZOOLOGISCHEN MIKROPALÄONTOLOGIE: VEB DEUTSCHER VERLAG DER WISSENSCHAFTEN, BERLIN. BAND I, xii+582 p., 549 TEXT-FIGS., DM 48. BAND II, viii +453 P., 1077 TEXT-FIGS., DM 48.

The most significant work published on micropaleontology has recently appeared by Dr. Vladimír Pokorný of Karls-Universität in Prague. It is a two-volume set from the press of VEB Deutscher Verlag der Wissenschaften in East Berlin, printed on excellent paper, profusely illustrated, and well bound. With a total of 1035 pages and 1626 figures in the text, this cannot be regarded as a German translation of Dr. Pokorný's 1954 one-volume Czech book, *Základy zoologické Mikropaleontologie*. It includes much more information, not only coverage of literature after 1954, but also revised sections on terminology, ontogeny, relationships, geographic distribution, and geologic range of each major taxon.

Essentially, the first volume is devoted to methods and Protozoa and the second to Metazoa. In addition to presenting a comprehensive survey of literature up to 1957 and part of 1958, this work contains some new information and taxa. Good bibliographies on divisions are offered at the end of each volume, followed by very useful and complete indices.

Band I starts with three chapters covering the definition of micropaleontology and a short historical résumé; methods of collecting and preparing samples, laboratory techniques of separating, mounting, and sectioning microfossils, and special ways of treating, studying, and photographing specimens; and the use of microfossils in various problems of correlation. The other seven chapters treat Radiolaria, Thecamoba, Foraminifera, Tintinnina, Incertae Sedis, Chi-

tinozoa, and Hystrichosphaeridea and similar organisms.

Undoubtedly, the chapter on Foraminifera will be studied by more micropaleontologists than all the others combined. The introductory material and classification differ sufficiently from those in other books to warrant discussion. The chapter begins with sections on form of the test, composition and wall structure, orientation of the test, morphology of various features (including proloculus, later chambers, septa and sutures, apertures, complicated walls and chambers, canal systems, and ornamentation), terminology, reproductive cycle, growth of test, ecology of living forams (15 pages), paleoecology (7 pages), descriptions, and basis of a natural system of classification (17 pages). In the last-named section, Pokorný stresses, in order: form of test, chemical composition and wall structure, complicated chamber structures, character of aperture, ornamentation, and sessility. As one might expect, his classification differs from that of Cushman and that of Glaessner.

Pokorný divides forams into nine superfamilies, eight of which contain 61 families as follows:

Allogromiidea
Astrorhizidea
  Saccamminidae
  Astrorhizidae
  Rhizamminidae
  Hyperamminidae
  Reophacidae
  Ammodiscidae
  Tournayellidae
  Lasiodiscidae
  Archaediscidae
Lituolidea
  Lituolidae
  Loftusiidae
  Textulariidae
  Semitextulariidae
  Trochamminidae
  Tetrataxidae
  Verneuilinidae
  Orbitolinidae
  Endothyridae
Fusulinidea
  Fusulinidae
  Neoschwagerinidae
Miliolidea
  Miliolidae
  Ophthalmidiidae
  Peneroplididae
  Alveolinidae
  Keramosphaeridae
Nodosariidae
  Polymorphinidae
  Enantiomorphinidae
Buliminidea
  Buliminidae
  Cassidulinidae
  Chilostomellidae
  Nonionidae
  Ellipsoidinidae
Spirillinidea
  Spirillinidae
Rotaliidea
  Rotaliidae
  Discorbidae
  Planorbulinidae
  Rupertiidae
  Pegidiidae
  Cymbaloporidae
  Ceratobuliminidae
  Epistominidae
  Robertinidae
  Orbulinidae
  Schackoinidae
  Hantkeninidae
  Globorotaliidae
  Heterohelicidae
  Amphisteginidae
  Elphidiidae
  Baculogypsinidae
  Miscellaneidae
  Nummulitidae
  Orbitoididae
  Pseudorbitoididae
  Lepidorbitoididae
  Discocyclinidae
  Orbitoclypeidae
  Helicolepidinidae
  Lepidocyclinidae
  Myogypsinidae

Devotees of the Cushman classification may be temporarily confused by such substituted familial names as Nodosariidae (=Lagenidae) and Orbulinidae (=Globigerinidae), by such recent families as Tournayellidae Dain 1953 and Lasiodiscidae Rejtlinger 1956, and by the expressed close relationships between Nonionidae and Buliminidae and between Elphidiidae and Rotaliidae. The family Schackoinidae is new in this volume; the appearance of new taxa in a comprehensive book is rather unexpected, but legal and not likely to be overlooked.

For each genus, the author, date, and type species are listed before the diagnosis and range. Unfortunately, the authors and dates of the superfamilies, families, and subfamilies are not given. One might wish for such information to decide for himself the status of certain suprageneric taxa. Special structures and techniques are discussed with the taxon to which they apply.

After the systematic descriptions, this chapter has 18 pages devoted to the geologic

distribution of Foraminifera, including first appearance, abundance, exit, and evolutionary trends in key genera and species. The chapter concludes with sections on the history of foraminiferal research and a German-English-French-Russian table of synonyms.

Other chapters in Band I follow the same general plan as that in the Foraminifera, with discussion of structure, morphology, ecology, geologic and geographic distribution, and phylogeny.

Band II contains chapters on Porifera, Octocorallia, Scolecodonta, conodonts, Ostracoda, Echinodermata, Ascidiacea, and Otolithi. As in other micropaleontologic works, there is no mention of Bryozoa.

The chapter on Ostracoda is of special interest. The systematic treatment of this taxon, considered by Pokorný to be a subclass, has progressed and expanded tremendously in the last decade. Preceding the *Treatise on Invertebrate Paleontology* volume on the Ostracoda, this chapter demands the close scrutiny of *Treatise* authors on the group, particularly with regard to new names.

The chapter starts with a definition of Ostracoda, followed by divisions on the soft parts, reproduction, morphology of the carapace, ornamentation, dimorphism, ontogeny, orientation of the carapace, ecology of living marine and freshwater ostracods, food, sequence for describing, origin of ostracods, and their phylogenetic development. Following the systematics, there are sections on geologic distribution and German-English-French-Russian synonyms.

Ostracoda are divided into the following orders, suborders, and families:

Leperditiida
- Leperditiidae

Beyrichiida
- Tetradellidae
- Eurychilinidae
- Přibylitidae
- Aparchitidae
- Acronotellidae
- Primitiopsidae
- Drepanellidae
- Beyrichiidae
- Hollinidae
- Neodrepanellidae
- Kirkbyidae
- Punciidae

Familiae incertae ordinis
- Alanellidae
- Leperditellidae
- Conchoprimitiidae
- Kloedenellidae

Podocopida

Platycopa
- Cytherellidae
- Healdiidae
- Thlipsuridae
- Barychilinidae
- Beecherellidae

Podocopa
- Macrocyprididae
- Bairdiidae
- Cyprididae
- Cytheridae
- Darwinulidae

Myodocopida

Myodocopa
- Cypridinidae
- Entomoconchidae
- Halocyprididae
- Entomozoidae
- Bolbozoidae

Cladocopa
- Polycopidae

The work provides four very useful features: (1) up-to-date coverage in each taxon, (2) listing of type species for each genus, (3) an extensive bibliography, and (4) discussion of morphology, ecology, distribution, ontogeny, etc. in each chapter. It is to be regretted that few American university students read German fluently, for this would make a good textbook for courses in micropaleontology. I highly recommend Dr. Pokorný's *Grundzüge* as a reference and guide to the advanced student and to the professional paleontologist.

ROBERT V. KESLING
Museum of Paleontology
University of Michigan

SOCIETY RECORDS AND ACTIVITIES

In accordance with Article 3, Chapter 1, of the By-Laws of the Paleontological Society, the names of new members approved by the Council are as follows:

BRAGDON, FREDERICK FAGAN, Weeks Trailer Camp, Storrs, Conn.: Walter Faustmann, Larry Frankel

JACKSON, DENNIS EDWARD, Pan American Petroleum Corp., 310 9th Ave. SW, Calgary, Alberta: John L. Severson, George J. Verville

JOHNSON, NIGEL EDWIN ALEXANDER, University Hostel, Stirling Highway, Nedlands, Western Australia: Brian F. Glenister, Basil Eric Balme

MACNEAL, DONALD LEVERNE, 852 So. Main Street, Towanda, Pa.: Erling Dorf, B. F. Howell

PESTANA, HAROLD RICHARD, 2480 Virginia Street, Berkeley 9, California: R. L. Langenheim, Joseph H. Peck, Jr., J. Wyatt Durham

SMITH, RAYMOND NEWTON, Box 147, Stafford, Conn.: Walter Faustman, Larry Frankel

TICE, WARREN KIMBALL, Weeks Trailer Park, Storrs, Conn.: Walter Faustman, Larry Frankel

WATERS, JOHN NELSON, 775 Oak Street, East Hartford, Conn.: Walter Faustman, Larry Frankel

THE PALEONTOLOGICAL SOCIETY

PROCEEDINGS OF THE FIFTY-FIRST ANNUAL MEETING HELD AT PITTSBURGH, PENNSYLVANIA

NOVEMBER 2–4, 1959

H. B. WHITTINGTON, *Secretary*

BUSINESS MEETING

The Annual Business Meeting of the Society was called to order at 2:00 P.M., Monday, 2nd November, with President Frank M. Swartz in the chair. About 60 persons were in attendance.

The Officers gave their respective reports, and a report on the work of the Treatise Committee was given by Professor Raymond C. Moore. These reports are given below. Verification by Council of the annual ballot for Officers was announced. Those elected to serve from the time of the fifty-first Annual Meeting until the next meeting in November 1960 are:

President—Kenneth E. Caster, Cincinnati, Ohio

Vice President—John W. Wells, Ithaca, N. Y.

Editor—R. V. Kesling, Ann Arbor, Michigan

Treasurer—C. C. Albritton, Jr., Dallas, Texas

Secretary—H. B. Whittington, Cambridge, Mass.

The incoming President, Kenneth E. Caster, then assumed the chairmanship of the Meeting and announced the nominations for Society Officers for the year 1960–1961. These nominations are given in a separate notice below. The attention of members was drawn to the Annual Luncheon, held on Tuesday, 3rd November (101 in attendance), and the President announced that a committee would be appointed to make arrangements for an Annual Luncheon next year.

SCIENTIFIC SESSIONS

Two sessions in paleontology, totaling five hours, were held on Monday, 1st November, the attendance being about 130. Following the Annual Business Meeting President Swartz's address was given. On Wednesday afternoon a three hour invitation program on plant microfossils in petroleum geology was held. This session was arranged in cooperation with the Paleobotanical section, Botanical Society of America. The Society also sponsored sessions in sedimentation and stratigraphy. The detailed programs of the scientific sessions, with abstracts, will be published in the bulletin of the Geological Society of America for December, 1959.

REPORT OF THE COUNCIL

The Council met for 8 hours on Sunday, 1st November. Apologies were received from W. R. Evitt. K. E. Caster and J. W. Wells

were present as members of the Council elect, R. L. Langenheim as President of the Pacific Coast section, and C. W. Collinson representing the S.E.P.M. Reports of officers and representatives on committees were read and accepted and appear below.

After discussion of the Editor's report the Council voted to continue the 300 line screen half tone reproduction for plates during the coming year. It was also voted that the Editor be authorized to refuse publication of papers containing more than 5 plates unless there is a subsidy for the plates in excess of 5. After discussion of the Treasurer's report it was voted to limit, for 1959–1960, the amount spent on publication of the three issues of the *Journal* to a total of $16,000.00, exclusive of any supplementary funds or new sources of income; this instruction is on the assumption that there is no significant rise in the costs of printing. The report of the committee which considered the committeee structure of the Paleontological Society was discussed and the results of this discussion are embodied in the notice appended regarding proposed changes in the Constitution. The report of the committee on the making of a merit award was considered, and it was voted that there be established a Paleontological Society medal for outstanding achievement in paleontology, this medal to be called the "Paleontological Society Medal." The President appointed G. Arthur Cooper as Chairman of a committee to prepare a design for the medal.

Chapter VII of the By-Laws of our Constitution provides for the establishment of a Publication Fund. Council discussed ways in which such a fund could be raised, and is continuing to explore actively such means. It is hoped that further information may be given in the next issue of the *Journal*.

The President announced the appointment of Charles W. Collinson and Eugene S. Richardson, Jr. to represent the Society at the Darwin Centennial celebration from November 24 to November 29 at the University of Chicago. The Council appointed the Secretary to be its representative at the International Geological Congress in Copenhagen, 1960. It was voted that the Paleontological Society should adhere to the International Paleontological Union. The Council further voted that a grant of $100,00 be made to the A.G.I. this year and $50.00 to the Zoological Record fund of the Zoological Society of London.

A hearty vote of thanks to the local committee for the arrangements made for the meetings at Pittsburgh is to be conveyed by the Secretary.

REPORT OF THE SECRETARY

To the Council of the Paleontological Society:

I have the honor to submit the following report for the year ending 2 November 1959:

46 new proposals for membership have come in during the year, many of these are listed in the *Journal*, vol. 33, p. 209, 530, 970. The membership now totals 837.

During the year the Society has lost 1 correspondent and 4 members by death:

Joaquin Frenguelli (Correspondent)
C. F. Deiss
W. H. Shideler
Walter C. Toepelman
G. Leslie Whipple

Respectfully submitted,
H. B. WHITTINGTON
Secretary

2 November 1959

AUDITOR'S REPORT

To the Council of the Paleontological Society:

We have examined the Treasurer's Report, here appended, and the vouchers, check book, and bank statements in the Treasurer's Office, and find them to be in order and correct as reported.

Yours very truly,
J. S. BRADLEY
W. W. SCHELL

REPORT OF THE TREASURER

To the Council of the Paleontological Society:

I have the honor to report the financial transactions of the Society for the term beginning November 1, 1958, and ending July 31, 1959.

Due to the change in dates for the beginning and end of the fiscal year, the term

of the following statement is nine rather than twelve months. Consequently, the total figures for receipts and disbursements cannot be compared directly with corresponding items in last year's report. Informally, it may be reported that on November 1, 1959, the reserve was more than a thousand dollars greater than the balance brought forward from November 1, 1958. This improvement is largely due to economies in publication effected by the Editor.

CLAUDE ALBRITTON, *Treasurer*

RECEIPTS

I. Balance brought forward from November 1, 1958			$ 5,062.08
II. Membership dues received:			
A. Dues from members receiving the *Journal of Paleontology* through the Paleontological Society:			
1960 dues:			
7 at $10.00	$ 70.00	$ 70.00	
1959 dues:			
269 at $10.00	2,690.00		
1 at $10.15	10.15		
1 at $10.50	10.50	2,710.65	
1958 dues: 6 at $10.00	$ 60.00	60.00	
1957 dues: 1 at $8.00	8.00	8.00	
Total dues from members receiving *Journal* through Paleontological Society			$2,848.65
B. Dues from members not receiving *Journal of Paleontology* through the Paleontological Society:			
1961 dues: 1 at $2.00	$ 2.00		
1960 dues: 4 at $2.00	$ 8.00		
1959 dues: 37 at $2.00	$ 74.00		
Total dues from members not receiving *Journal* through Paleontological Society		84.00	
Total membership dues received	$2,932.65		
plus exchange profit on Canadian ck.	+.26		
less bank service chg on Unesco coupon (2 at 50¢)	−1.00		
Total membership dues accrued			$ 2,931.91
III. Contributions in support of the *Journal of Paleontology*, received from the Penrose Bequest of the Geological Society of America:			
January 1959 issue	$4,240.31		
May 1959 issue	2,259.69		
Total, contributions in support of the *Journal of Paleontology* received from the Penrose Bequest of the Geological Society of America			$ 6,500.00
IV. Apportioned income received from subscriptions and sales, *Journal of Paleontology*:			
1958 remittance from Society of Economic Paleontologists and Mineralogists	$3,371.57		
			$ 3,371.57
V. Income received from sale of reprint of Symposium on Explosive Evolution, 3 at $2.00	$ 6.00	$ 6.00	
TOTAL RECEIPTS			$17,871.56

DISBURSEMENTS

(Check Numbers given in parentheses)

I. Publication expense, *Journal of Paleontology:*			
January 1959 issue			
Plates and authors' reprints (391)	$1,627.92		
Printing (394)	4,149.48		
		$5,777.40	
May 1959 issue			
Plates and authors' reprints (396)	$ 867.84		
Printing (401)	3,157.66		
		$4.025.50	
Half cost, annual index for 1958 (402)		83.04	
Total, disbursements for publication expense of *Journal of Paleontology*			$ 9,885.94
II. Publication expense, other than for publication of *Journal of Paleontology:*			
Correspondents of the Paleontological Society			
9 members at $7.70 per member (395)	$ 69.30		69.30
III. Special supporting contributions			
American Geological Institute (386)	$ 100.00		
Zoological Society of London (387)	50.00		
Total, special supporting contributions			150.00
IV. Expenses of Offices of the Society			
A. Secretary's Office			
Travel subsidy, 1958 meetings (384)	$ 118.00		
Printing, letters for new members (390)	7.25		
Printing, gummed labels for envelopes (392)	3.00		
Services of GSA office in correcting and revising membership files of PS (393)	46.50		
Addressing envelopes for mailing ballots (399)	49.50		
Printing nomination blanks and ballots (400)	21.18		
		245.43	
B. Editor's Office			
Secretarial expense, postage, etc. (385)	$ 200.00		
		200.00	
C. Treasurer's Office			
Postage (388)	$ 22.73		
Postage (398)	19.79		
Security Bond (389)	5.00		
Printing, envelopes (397)	19.50		
		67.02	
Total, disbursements for expenses of Offices of Society			512.45
TOTAL, DISBURSEMENTS FOR FISCAL PERIOD ENDING JULY 31, 1959			10,617.69
Cash-on-hand, July 31, 1959, in Hillcrest State Bank, University Park, Dallas, Texas.			7,253.87
Total, disbursements for fiscal period November 1, 1958 through July 31, 1959, plus cash-on-hand, July 31, 1959			$17,871.56

REPORT OF THE EDITOR FOR 1959

The Paleontological Society in the January, May, and September issues of the *Journal of Paleontology* for 1959 published 35 articles on invertebrate paleontology, 9 on micropaleontology, 7 on vertebrate paleontology and 5 on paleobotany in addition to nomenclatural notes, notices, and Society proceedings and records. The total of 610 pages and 80 plates compared with 748 pages and 102 plates for the 1958 issues represents a decrease of 18% in number of pages and a decrease of 20% in number of plates.

The use of 300 mesh halftone offset reproductions instead of collotype in the plates for the May and September numbers resulted in a saving of 17%.

The paper entitled "Brachiopods of the Lower Devonian rocks at Highland Mills, New York" by A. J. Boucot comprising 43 pages and 14 plates in the September number was referred to us by the Geological Society of America, which will pay the cost of its publication.

Beginning with the January, 1960 number the run will be increased from 2,500 to 2,600 to cover increased demand.

As of October 12, 1959 the editor has on hand 43 manuscripts totaling 1,125 manuscript pages and 59 plates. This compares with a backlog of 1,478 manuscript pages and 77 plates as of October 13, 1958.

TABLE 1. TOPICAL ANALYSES OF CONTENTS OF THE PALEONTOLOGICAL SOCIETY'S NUMBERS OF THE JOURNAL OF PALEONTOLOGY

Year	1954	1955	1956	1957	1958	1959
Volume	28	29	30	31	32	33
Pages of:						
Invertebrate Paleontology	355	429	418	537	452	402
Mincropaleontology	9	49	150	51	193	90
Vertebrate Paleontology	60	101	207	53	74	52
Paleobotany	11	8	19	8	11	38
Notices and Records	17	5	18	34	18	28
Total Pages	432	592	812	683	748	610
Plates	52	73	92	72	102	80

Respectfully submitted,
ERWIN C. STUMM
Editor

BALLOTING REPORT

To the Council of the Paleontological Society:

We, the undersigned, have examined the ballots returned to the Secretary's office by October 17 in the Annual Vote of the Paleontological Society and find the following results:

1. Total number of ballots returned—386.
2. Ballots invalidated by (a) absence of name on mailing envelope—60, or (b) name on inner envelope—8.
3. On the 318 valid ballots the vote was as follows:

	For	*Against*	*Blank*
(a) *President* Kenneth E. Caster	314	3	1
(b) *Vice President* John W. Wells	315	1	2
(c) *Secretary* Harry B. Whittington	317	0	1
(d) *Treasurer* C. C. Albritton, Jr.	317	0	1
(e) *Editor* R. V. Kesling	311	4	3

Respectfully submitted,
CRAIG C. BLACK
ALLEN S. HUNT

REPORT OF THE PALEONTOLOGICAL SOCIETY REPRESENTATIVE ON THE NATIONAL RESEARCH COUNCIL, DIVISIONS OF EARTH SCIENCES AND BIOLOGY AND AGRICULTURE, 1959

For the second straight year the National Research Council met as a body, with only one afternoon being devoted to divisional meetings. One topic discussed this year was scholarships and grants. Some of the items covered include ways to insure more long term grants, the question of large expenditures for equipment and buildings, and better methods of selecting grantees. One is left with the impression that much more money is being distributed annually from public and private funds than is commonly realized.

An exchange of scientists has been negotiated between the National Academy of Sciences and the Soviet Academy of Sciences. International exchange of scientists is also scheduled to be discussed at the International Geological Congress at Copenhagen.

A steering committee has been appointed by the U. S. National Committee of the International Union of Biological Sciences to begin planning for the 16th International Zoological Congress meeting in the United States (1963). No announcements have been released so far.

The Division of Medical Sciences has offered a unique opportunity for paleontology to have a role in outer space studies. A subcommittee on extra-terrestrial life has been formed under the newly organized Armed Forces-NRC Committee on Bio-Astronautics. The aim is to study biology of organisms that may have developed extra-terrestrially and the reaction of terrestrial life to this strange environment. Although most of the work so far has been along the lines of organic chemistry and microbiology, the subcommittee was interested in the suggestion that paleontology might be able to contribute ideas on unusual life forms or ecologic niches. Anyone with an idea along these lines is urged to speak up.

In the Division of Earth Sciences, two items are of interest to the paleontologist. The first is the Mohole committee which has issued a report "Drilling through the earth's crust" (NRC publication 717). Site selection studies are underway for a moderately deep hole at sea. The second item is the report "Oceanography 1960–1970" issued by the interdivisional committee on Oceanography. Part 1, "Introduction and Summary" is in a second printing. Of the eleven additional chapters treating phases of the report in detail, parts 3, 5, 6, 7, 8, 10, and 12 are printed. The others are to be completed in the immediate future.

Respectfully submitted,
ELLIS L. YOCHELSON

REPORT OF THE JOINT COMMITTEE ON INVERTEBRATE PALEONTOLOGY, PREPARING THE TREATISE ON INVERTEBRATE PALEONTOLOGY

Steady progress, even though at slow pace, can be reported in advancing the *Treatise* project. This is indicated by publication of the volume designated Arthropoda I, concerned mainly with the Trilobita, comparable in size with the volumes on coelenterates and ammonoids. It contains 470 pages and very numerous illustrations, comprising materials contributed by 18 authors, and marks the eighth completed unit.

The next volume to appear will be Part I, Mollusca I, which contains a general introduction to the Mollusca by C. M. Yonge, of the University of Glasgow; description of fossil Scaphopoda by N. H. Ludbrook, of Australia; Amphineura, by A. G. Smith, California Academy of Sciences; Monoplacophora, by J. B. Knight, Smithsonian Institution, and E. L. Yochelson, U. S. Geological Survey; Introduction to Gastropoda, by L. R. Cox, British Museum (Natural History); and systematic descriptions of Archaeogastropods (mainly Paleozoic), and some other Paleozoic gastropods, by J. B. Knight, R. L. Batten, E. L. Yochelson, L. R. Cox, Myra Keen, and Robert Robertson. This volume, which is now in page-proof stage of preparation, will be nearly as large as the last-issued one on trilobites and should be ready for distribution early in 1960.

Materials for the *Treatise* volume concerned mainly with Ostracoda are nearing

readiness for press. This unit will be the next to follow Part I on Mollusca.

For the Joint Committee on
Invertebrate Paleontology
RAYMOND C. MOORE,
Chairman
1 November 1959

REPORT OF THE REPRESENTATIVE OF THE PALEONTOLOGICAL SOCIETY ON THE COMMITTEE AND COUNCIL FOR SECTION E—GEOLOGY AND GEOGRAPHY—OF THE AAAS

The annual meeting, which I attended, was held in Washington, D. C., December 26–30, 1958. The sessions consisted of symposia on the history of American geology and experimental geology, a vice-presidential address by Robert R. Shrock on "Primary Structures in Sedimentary Deposits," a meeting of Section E Committee to discuss plans for the 1959 program of the Section, and a meeting of the AAAS Council.

While this annual meeting had very little which was directly related to paleontology, I feel that it is important that we keep our affiliation with the AAAS. As you know, a number of very prominent paleontologists have been president of the AAAS in its earlier history. Representation by The Paleontological Society on the Section Committee assures the Society that paleontology will receive proper consideration for future programs. We will continue to receive recognition by our colleagues from other societies represented on the Council. As a matter of fact, you will be interested to know that The Paleontological Society was represented by two men last year, Professor Cecil Kindle of City College of New York and myself. Several papers in the symposium on the history of American geology touched on paleontology, one in particular, by Dr. John A. Wilson entitled "Darwinian Natural Selection and Vertebrate Paleontology" dealt directly with the field.

I want to call attention to the annual meeting of the AAAS, December 26–31, 1959 to be held in Chicago. Section E—Geology and Geography is planning two programs, one on quantitative terrain studies and the other on the Great Lakes Basin. It does not appear from the titles that paleontology will be directly considered but we will be represented in the Committee meeting for suggestions for next year's meeting.

I would like to call attention also to the fact that any of the members of The Paleontological Society membership who are now members of the AAAS but not fellows, may be considered for fellowship in the latter organization. If there are any matters which the membership would like to have brought before the AAAS Council on Section E Committee, I shall be happy to make these at the meeting in Chicago during the Christmas vacation.

Respectfully submitted,
R. C. GUTSCHICK

REPORT ON THE AMERICAN GEOLOGICAL INSTITUTE

Paleontological Society Representatives:

Allison Palmer
A. G. Fischer

The American Geological Institute is an Association of the various geological societies of the United States, and its function is to unite and represent the profession as a whole. It has been supported by its member societies, each of which is represented on the AGI board of "directors" by two men.

The program of the AGI is briefly reviewed below. Aside from this, the principle new developments of the past year have been:

(1) Better liaison between the AGI and the member societies through monthly reports, distributed to the council of the PS, for example, through one of its representatives.

(2) The Croneis report, an evaluation of AGI and its problems, including appraisals of AGI program, AGI financing etc. by various member societies and individual geologists, gathered and supplemented by Dr. Carey Croneis. This report has not been published and is still in preliminary form, but its content should be of great influence in the future development of AGI. The writer calls special attention to the GSA's appraisal of AGI, as formulated by the Bucher committee.

Financing continues to be a critical ques-

tion with AGI. The profession is contributing about $75,000 per year, and NSF grants about $250,000 per year. Without such grants the AGI program would largely collapse. AGI is thus not on a sound financial basis for carrying out and broadening its program.

The AGI Program

The following briefly summarizes the current AGI program:

Education.—(1) Visiting geoscientist program (45 visitors have visited over 70 smaller colleges). (2) Planned for next year: an additional program of visiting scientists from abroad. (3) Teaching resources development program—the Duluth conference, directed toward the problem of teaching earth sciences in high school. (4) Career guidance program: Continued distribution of career booklets. (5) Visual education program—film reviews, with intent to publish an annotated list of geological films. (6) Boy Scout committee.

Public relations.—A small program due to lack of funds. Mission 66—geological advice to National Park Service, by local geological groups.

Professional relations.—(1) Professional standards, currently under study. (2) Employment—articles and surveys in Geotimes. (3) Long-range calendar of geological meetings. (4) Translation program: (a) International Geology Review, (b) translations of current Russian journals (Izvestya and Doklady), (c) translations of specific books (Beloussov and Nalivkin). (5) Geoscience abstracts, now covering 75% of North American literature. (6) Study of a possible International Abstract Journal.

Government relations.—Register of Earth Scientists.

Other publications.—(1) 1960 College Directory of the Geosciences (due for distribution in November). (2) 1959 survey of students. (3) Supplement to the 1957 edition of the Glossary. (4) Geotimes, now distributed to 28,500. (5) A brochure on the member societies.

Among the problems to be discussed at the AGI board meeting in 1959 will be possible changes in the constitution toward several ends: The possibility of admitting individual members to AGI; the possibility of having AGI charge member Societies per member, perhaps in exchange for acting as a centralized mailing agency for all member societies; the possibility of having member societies take a more active hand in the direction of AGI; and other points brought out in the Croneis report. Also possible withdrawal from Nat. Acad. Sci. auspices.

Respectfully submitted,
A. G. FISCHER

NOMINATIONS FOR OFFICERS IN THE PALEONTOLOGICAL SOCIETY FOR 1960–1961

In accordance with the provisions of Chapter III, Section 1 and 2 of the By-Laws, the Council of the Paleontological Society announces the following nominations for the offices in the Society for 1960–61:

For *President*—NORMAN D. NEWELL, New York, N. Y.
For *Vice President*—SIEMON W. MULLER, Stanford, California
For *Secretary*—H. B. WHITTINGTON, Cambridge, Mass.
For *Treasurer*—CLAUDE C. ALBRITTON, JR., Dallas, Texas
For *Editor*—ERWIN C. STUMM, Ann Arbor Michigan

In accordance with Chapter III, Section 2 of the By-Laws it is provided that "Any twenty members may forward to the Secretary other nominations for any or all offices. All such nominations reaching the secretary at least sixty days before the Annual Meeting shall be printed, together with the names of the nominators, as special tickets."

NOTICE TO ALL MEMBERS REGARDING PROPOSED CHANGES IN THE CONSTITUTION AND BY-LAWS OF THE PALEONTOLOGICAL SOCIETY

At its meeting on 1st November 1959 in Pittsburgh, the Council considered the report of a committee appointed by the President to examine our Constitution and By-Laws with special reference to the election of Officers, and to recommend desirable changes. Council proposed that the follow-

ing changes in the Constitution should be made:

Article III, paragraph 8, of the present Constitution (see Proceedings Volume of the Geological Society of America for 1948, pp. 267–272; subsequent changes are reported in the *Journal*, volume 29, p. 192; volume 32, p. 646) now reads:

"*Terms of Office.* The Officers shall be elected annually. The President shall not be eligible for re-election until after an interval of three years from retirement from office. A Vice-President shall be eligible for re-election not more than once within such interval.

The Secretary, Treasurer, and Editor shall be eligible for re-election for not more than ten consecutive terms of one year each. There shall be no restriction on the re-election of an Assistant Secretary."

It is proposed that Article III, paragraph 8 shall read:

"*Terms of Office.* The Officers shall be elected annually. The President shall not be eligible for re-election as President or Vice-President. The Secretary, Treasurer or Editor shall be eligible for re-election for not more than eight consecutive terms of one year each."

Chapter III, paragraphs 1 and 2 of the By-Laws now read as follows:

"1. The Council shall prepare a list of nominations for the several offices, which list shall constitute the regular ticket. This ticket must be approved by a majority of the entire Council. The nominee for President shall not be a member of the Council.

"2. The Council, in preparing its nominations, shall consider suggestions made by the membership, in writing prior to the Annual Meeting. For the convenience of the membership, blanks which may be used for this purpose shall be provided with the annual ballot."

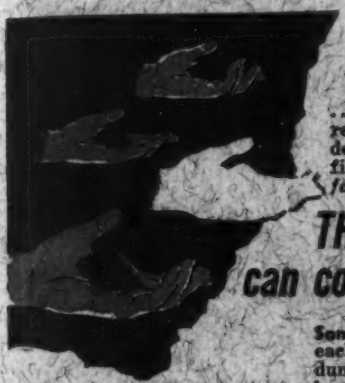
It is proposed that Chapter III, paragraphs 1 and 2 shall read:

"1. A Committee on nominations shall be appointed each year by the President, consisting of three Society members who are not members of the Council, and the Secretary *ex-officio* who shall not vote. The Nominating Committee shall submit three names each for President and Vice-President, and one (or more) for each of the offices of Secretary, Editor and Treasurer. The Council shall then select one name for each office from the nominations and these shall constitute the regular ticket. This ticket must be approved by a majority of the entire Council.

"2. The Nominating Committee shall consider suggestions made by the membership, in writing prior to the Annual Meeting. For the convenience of the membership, blanks which may be used for this purpose shall be provided with the annual ballot."

This proposal will be the subject of a ballot of the membership, to be taken at the same time as the next annual ballot for officers in September, 1960. As provided in the Constitution, this document may be amended by a two-thirds vote of the ballots cast by a mail ballot of the membership. Attention is drawn to the provision in the Constitution (see Notice of Candidates for Offices for 1960–1961) for additional nominations for office that may be made by twenty or more members.

H. B. WHITTINGTON
Secretary



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TELESCOPIC PLANE TABLE ALIDADE

(by E. R. WATTS)

Alidade is of brass and 15 in. in length. The telescope has an object glass diameter of 30 mm and has internal focussing. Arc engraved 0-10° elevation and depression. Reading by vernier to minutes by microscope reader. Packed in fitted mahogany case. These are modern unused instruments released to us by the Ministry of Supply. Offered at **$59** *Post and packing $1.50*

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GEIGER COUNTER

DETAILS ON REQUEST

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An extremely compact Clinometer measuring 2¾ in. in diameter and weighing only 6 ozs. Angles of up to 45° elevation and depression can be read instantly to an accuracy of 1° or interpolated to 15 minutes. Complete in leather case. Brand new condition.

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HELIOGRAPHS

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CHARLES FRANK

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